BBC

TRAPPIST-1 PLANETS: WHAT WE KNOW NOW

THE UK'S BIGGEST SELLING ASTRONOMY MAGAZINE

Sky at Night

FEBRUARY 2018 153

OBSERVING SPECIAL

DIAMONDS OF THE WINTER SKY

Discover sparkling views with 12 of this season's most spectacular star clusters

THE LUNAR X

Watch as sunlight reveals hidden shapes on the Moon

VIRTUAL UNIVERSE

Tested: 9 VR apps that will launch you into space

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

2018's competition now open for entries

EXTRA ONLINE

VIDEO INTERVIEW
We speak to the astronomer who led the discovery of TRAPPIST-1

WATCH THE SKY AT NIGHT
Get back to basics with a lesson in astronomy

INTERACTIVE PLANETARIUM
Our audio-visual guide to February's night sky highlights

This month's contributors include...

Jen Gupta
Astrophysicist

Jen explains why the night sky is awash with colour – why stars shine red, blue and gold. *Page 21*

Pete Lawrence
Astro imager

Pete's scientific imaging series continues with asteroids, the space rocks zipping through our Solar System. *Page 76*

Chris Lintott
Sky at Night presenter

What do you do when your observations don't agree? Chris delves into one of the enduring challenges of particle physics. *Page 14*

Louisa Preston
Planetary geologist

Louisa takes a close look at TRAPPIST-1, the system with seven rocky worlds that's rocked the space science community. *Page 39*

Welcome

Wrap up warm and step outside – the skies await

There can be a real chill in the air when you're out under clear night-time skies at this time of year, so what's on your observing list better be worth it. Luckily, on page 32 we have Will Gater to take us on a tour of 12 of the most exciting star clusters to see in this month's skies. Whether you have a scope or a pair of binoculars, there'll be something for you.

Once you've seen those, you'll find the rest of the month's best observing in the Sky Guide, from page 49. Pete Lawrence and Stephen Tonkin are your guides to this month's planets, stars, asteroids, artificial satellites and more. Don't forget to wrap up warm!

It's doubtful that you'd need winter clothing on the exoplanets that are the topic of our feature on page 39: all seven worlds around the star TRAPPIST-1 orbit closer than Mercury does to the Sun. One year on from the discovery, Louisa Preston considers what we've learnt about surface conditions and the possibility of life in this remarkable planetary system.

Although we're unlikely to get to TRAPPIST-1 in person (it's 40 lightyears from Earth), judging by the progress of virtual technologies we may well be able to visit an imagining of it soon. On page 70, Elizabeth Pearson explores the virtual reality experiences out there for astronomers today – everything from VR tours of the International Space Station and documentaries of the Apollo 11 landings to star charts you can fly through to visit the planets of the Solar System.

Enjoy the issue!

Chris Bramley Editor

PS Our next issue goes on sale on 15 February.

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Sky at Night Lots of ways to enjoy the night sky...

TELEVISION
Find out what *The Sky at Night* team will be exploring in this month's episode on page 19

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All the details of our latest issue, plus news from the magazine and updates to our website

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The *BBC Sky at Night Magazine* team discuss the latest astro news in our podcast

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Follow @skyatnightmag to keep up with the latest space stories and tell us what you think

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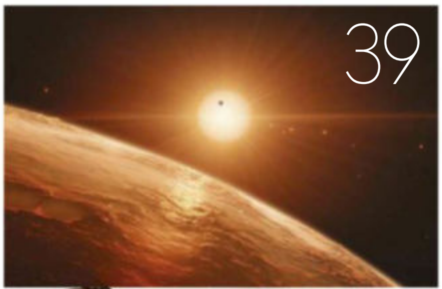

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FEBRUARY'S BONUS CONTENT

THERE'S MORE ONLINE

HOW TO FIND IT

Visit **www.skyatnightmagazine.com/bonuscontent**, select February's bonus content from the list and enter the authorisation code **4WG6WUJ** when prompted

February highlights

Watch *The Sky at Night*

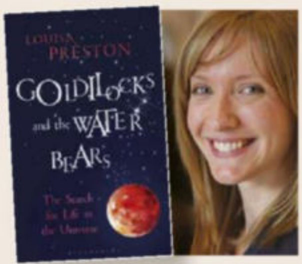
The team get back to basics with a lesson in appreciating the majesty of the night sky. Chris Lintott learns how to navigate using the positions of the stars, while Pete Lawrence gets a group of young people excited about stargazing. Maggie Aderin-Pocock travels to Norway in search of one of the most magnificent displays the night sky has to offer.

Michaël Gillon: how to find an exoplanet

The leader of the TRAPPIST-1 team reveals how they made one of the biggest discoveries of the past year.

Interview with an asteroid hunter

Asteroid expert Tim Spahr talks about the science of space rocks, and whether they are a threat to Earth.



Audiobook download: the search for life

Louisa Preston, writer of this month's TRAPPIST-1 feature, examines the hunt for extraterrestrial life.

EVERY MONTH
Virtual Planetarium

With Paul Abel and Pete Lawrence

Explore February's night-sky highlights with Paul and Pete.

and much more...

- ▷ Hotshots gallery
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- ▷ Binocular tour
- ▷ Equipment review guide
- ▷ Desktop wallpaper
- ▷ Observing forms
- ▷ Deep-sky tour chart

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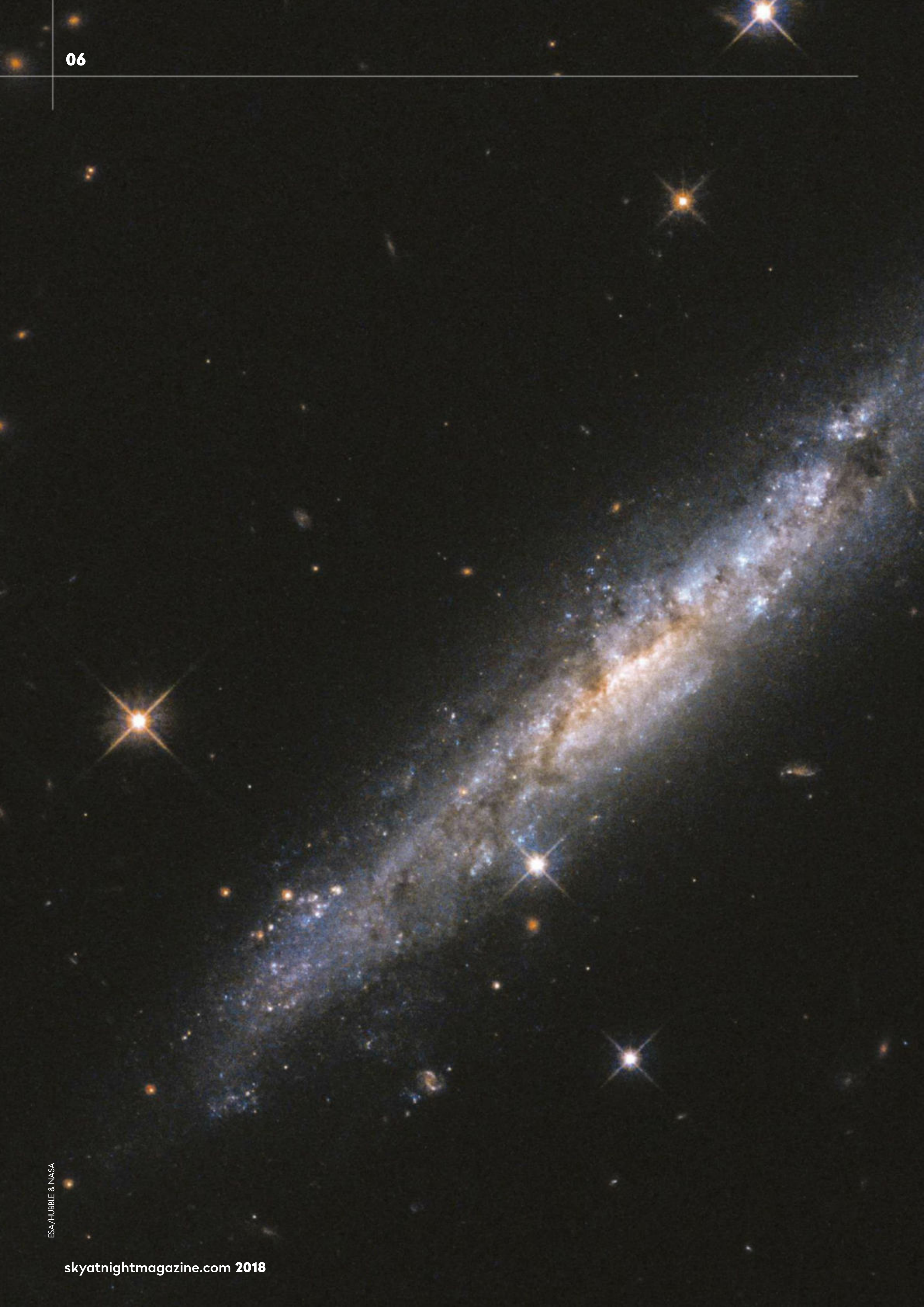


ESA/HUBBLE & NASA

Gamma-ray GALAXY

Astronomers believe this galaxy may be the scene of a colossal explosion that blasted out beams of high-energy radiation; one of the closest such explosions to Earth ever observed

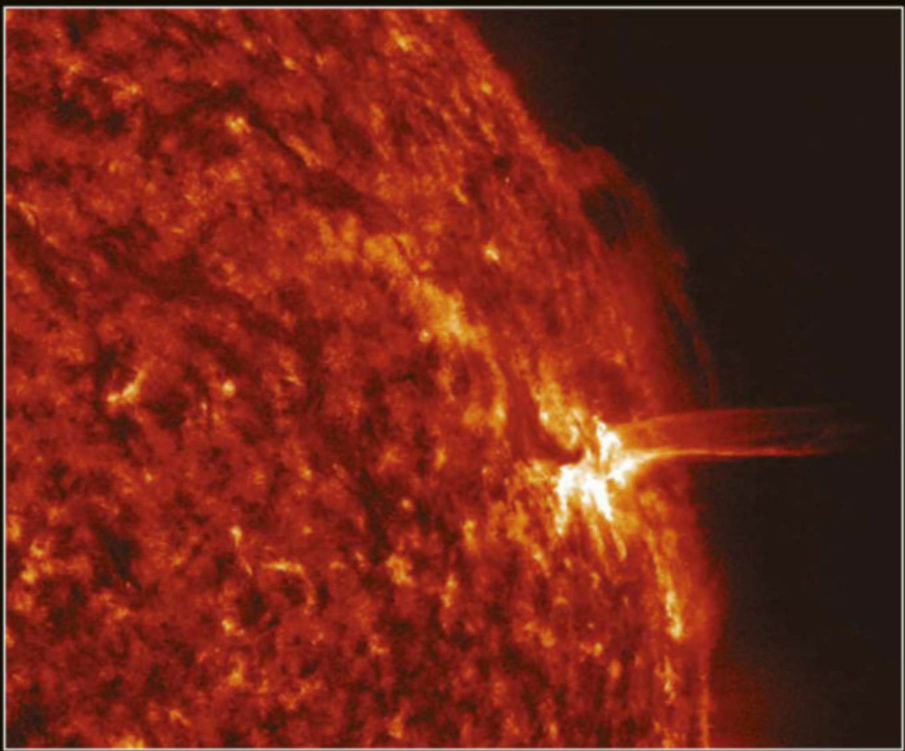
HUBBLE SPACE TELESCOPE, 4 DECEMBER 2017

While this Hubble image has just been released, its galactic subject has been studied for the best part of a decade by astronomers keen to get to the bottom of an explosive mystery. In October 2011, a gamma-ray burst (GRB) was observed coming from the area of the sky in which this spiral galaxy, named ESO 580-49, resides.

GRBs are fleeting bursts of high-energy gamma-ray radiation, and they are the brightest electromagnetic events known to occur in the Universe. Their exact cause remains a mystery. However, considering the amount of energy given off during these explosions, they are likely to be triggered by a colossal cosmic event. It is thought they may be generated by the collision of neutron stars or black holes, or even the collapse of a very hot, massive kind of star known as a Wolf-Rayet.

While several theories exist as to the cause of GRBs, none of them seem to match the event recorded here. Perhaps this galaxy was the host of a new type of GRB: one that has not yet been catalogued. Astronomers think that this magnificent spiral galaxy was the source of the GRB because the explosion occurred in the same region of the sky; the chance of it only appearing to come from within the galaxy and being a sheer coincidence is about one in 10 million.

The event, known as GRB 111005A 580-49, occurred about 185 million lightyears from Earth, making it the second-closest GRB to our planet ever detected.



▲ Finding faults

MARS RECONNAISSANCE ORBITER,
11 DECEMBER 2017

NASA's Mars Reconnaissance Orbiter obtained this image of the Meridiani Planum, a region near the Martian equator. It shows how faults on the Red Planet have disrupted deposited material on the surface, creating patterns that resemble the growth rings seen on exposed wood.

◀ Protruding prominence

NASA SOLAR DYNAMICS OBSERVATORY,
29-30 NOVEMBER 2017

This prominence was seen erupting from the surface of the Sun by NASA's Solar Dynamics Observatory. Prominences are strands of plasma that flow along the Sun's magnetic field lines. Occasionally they erupt into space and create incredible features like the one seen here.

What's the matter? ▶

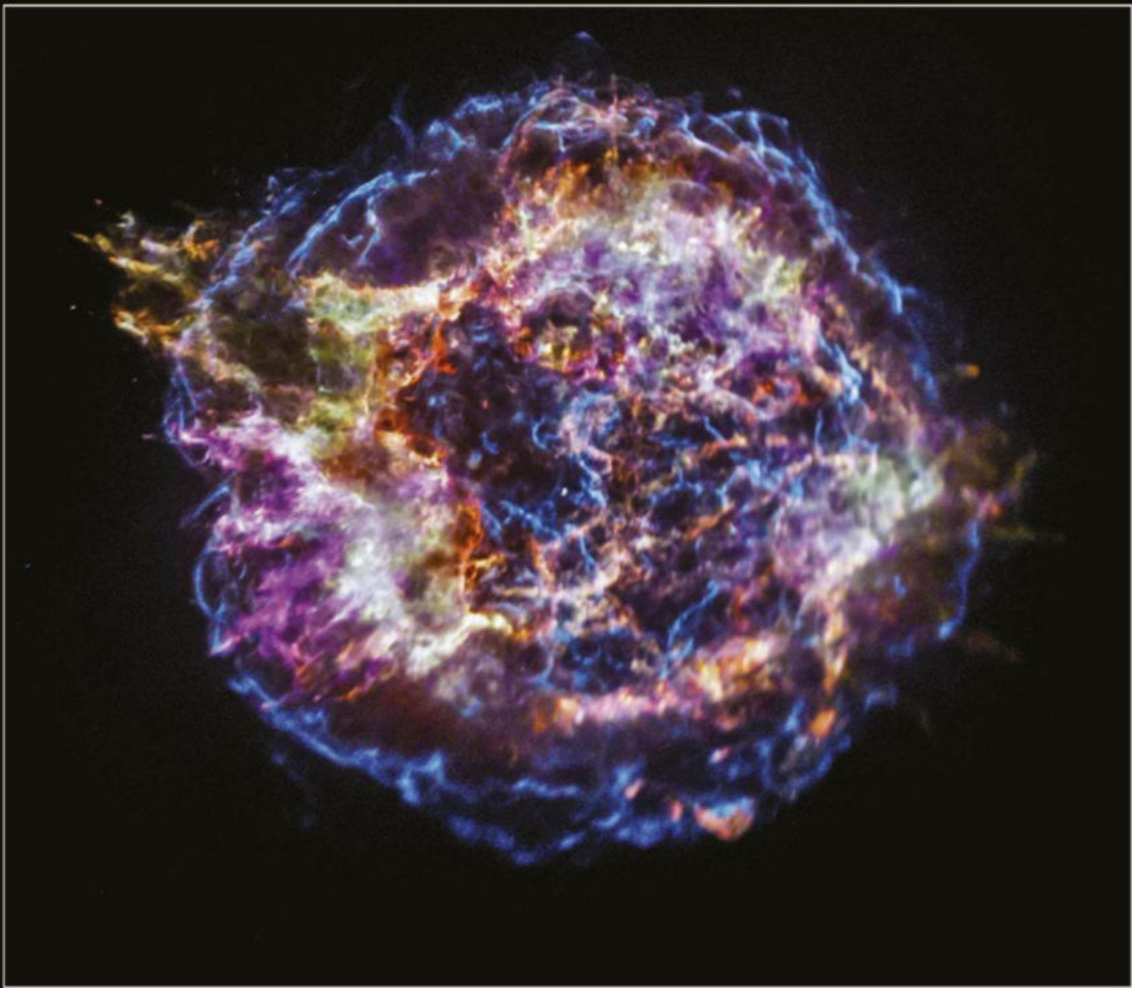
HUBBLE SPACE TELESCOPE,
11 DECEMBER 2017

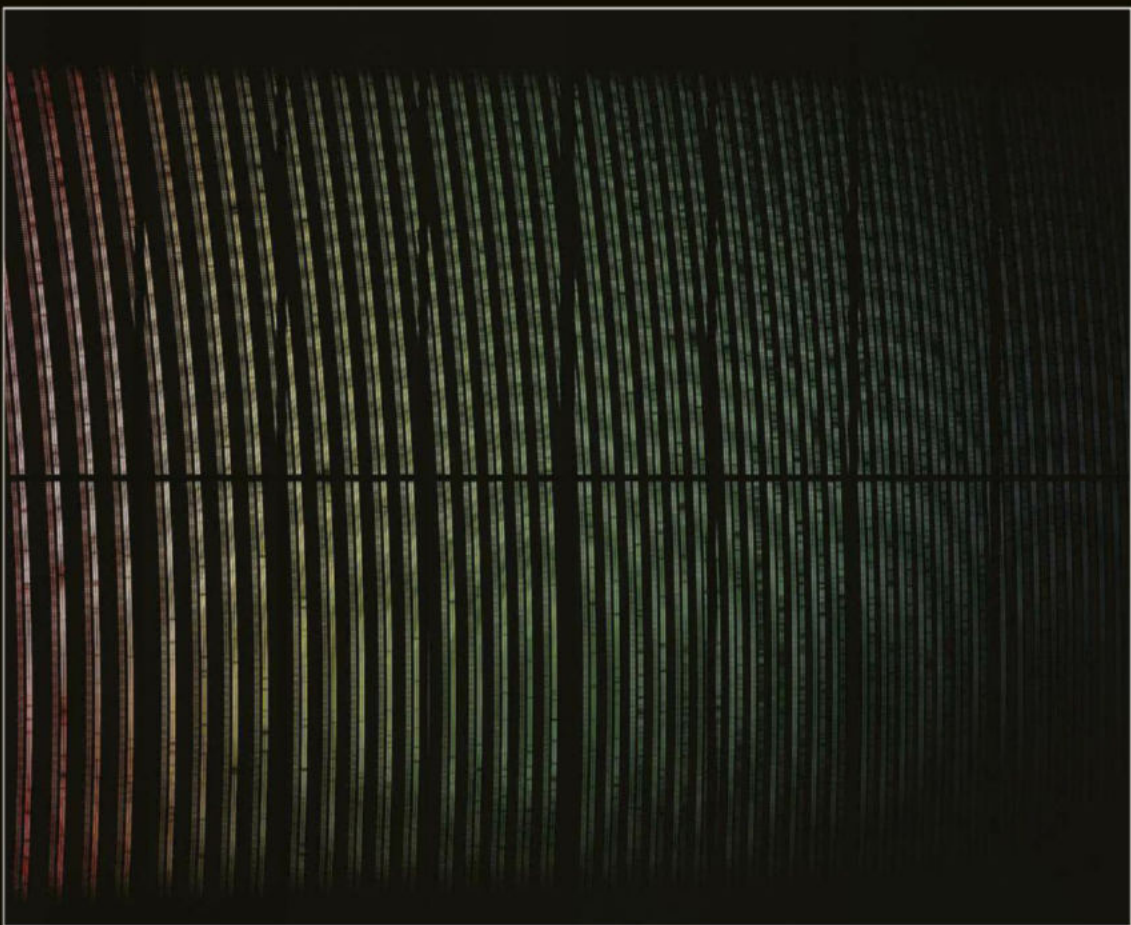
Most of the fuzzy blobs and pinpricks here are individual galaxies, together making up galaxy cluster Abell 2163. The study of galaxies and clusters throughout the 20th century revealed that all their visible mass couldn't provide the required gravitational pull to hold them together. This led to the theory of dark matter, and studying how galaxy clusters operate is one way of learning more about this mysterious substance.

▶ We are made of star stuff

CHANDRA X-RAY OBSERVATORY, 12 DECEMBER 2017

Many of the elements that make up our bodies and the world around us come from the scorching furnaces of stars. Astronomers study supernova remnants – the remains of exploded stars – to learn more about how stars make and distribute these elements throughout the Universe. Cassiopeia A is one of the most studied. Chandra observations revealed the iron in Cassiopeia A has the mass of about 70,000 Earths, and detected the ejection of oxygen equivalent to about three times the mass of the Sun.





◀ Splitting starlight

VERY LARGE TELESCOPE (VLT), 6 DECEMBER 2017

These colourful bands respresent data collected by the VLT's ESPRESSO (Echelle Spectrograph for Rocky Exoplanet and Stable Spectroscopic Observations) instrument. It shows dispersed starlight and was collected during ESPRESSO's first light. Astronomers are looking for variations in this data that might indicate a rocky, Earth-like planet in orbit.

Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

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Our experts examine the hottest new astronomy research papers

Like Earth, the newly discovered planet Kepler-90i is the third rock from its sun

Distant planetary system RIVALS OUR OWN

Kepler-90 has eight rocky and gas giant planets

Astronomers have anounced that there is another star system containing eight planets, tying it with our own Solar System for the most number of known worlds. We already knew of seven around the Sun-like star Kepler 90 in Draco, among which is a Jupiter sized gas giant; the recently discovered eighth planet was found in data gathered with the Kepler space telescope using artificial intelligence. The new planet, Kepler-90i, is the third out from the star, is 30 per cent larger than Earth and has an orbit of 14.4 days.

"The Kepler-90 star system is like a mini version of our Solar System," says Andrew Vanderburg, an astronomer from the University of Texas who took part in the study. "You have small planets inside and big planets outside, but everything [in Kepler-90] is scrunched up closer."

The planet was found using a neural network – a computer program that learns how to analyse data by example, rather than having set rules. Vanderburg, along with a Google machine-learning researcher, trained the network using 15,000 previously vetted exoplanet detections. The program then re-examined Kepler data from stars that are already known to host planets, looking for worlds that were missed the first time.

The project found new planets around two stars – the eighth planet around Kepler-90 and a sixth world around Kepler-80.

"New ways of looking at the data – such as this early-stage research to apply machine learning algorithms – promise to continue to yield significant advances in our understanding of planetary systems around other stars," says Jessie Dotson, Kepler's project scientist at NASA's Ames Research Center. "I'm sure there are more firsts in the data waiting for people to find them."

▸ **See Comment, right**

NASA/AMES RESEARCH CENTER/WENDY STENZEL

COMMENT
by Chris Lintott

If you listened carefully during the press conference announcing this work, you could hear the eye-rolling. The journalists and astronomers on the line and, later, on Twitter, just weren't hugely impressed with the discovery.

Yes, this is the first system with eight confirmed planets, but by now we know planets, and multi-planet systems, are common. Anyone who thought that our Solar System had a lock on the 'most planets' title was bound to disappointed sooner rather than later.

And yes, the discovery was made with 'Google artificial intelligence', but groups around the world have been turning machine learning to the cause of planet detection for years. The paper is great, but hardly Earth-shattering.

That's what exoplanet life is like now. A steady drip of discoveries, with each one pinning a new world onto the map of the cosmos. Maybe that's enough. A new planet is always cause for celebration.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

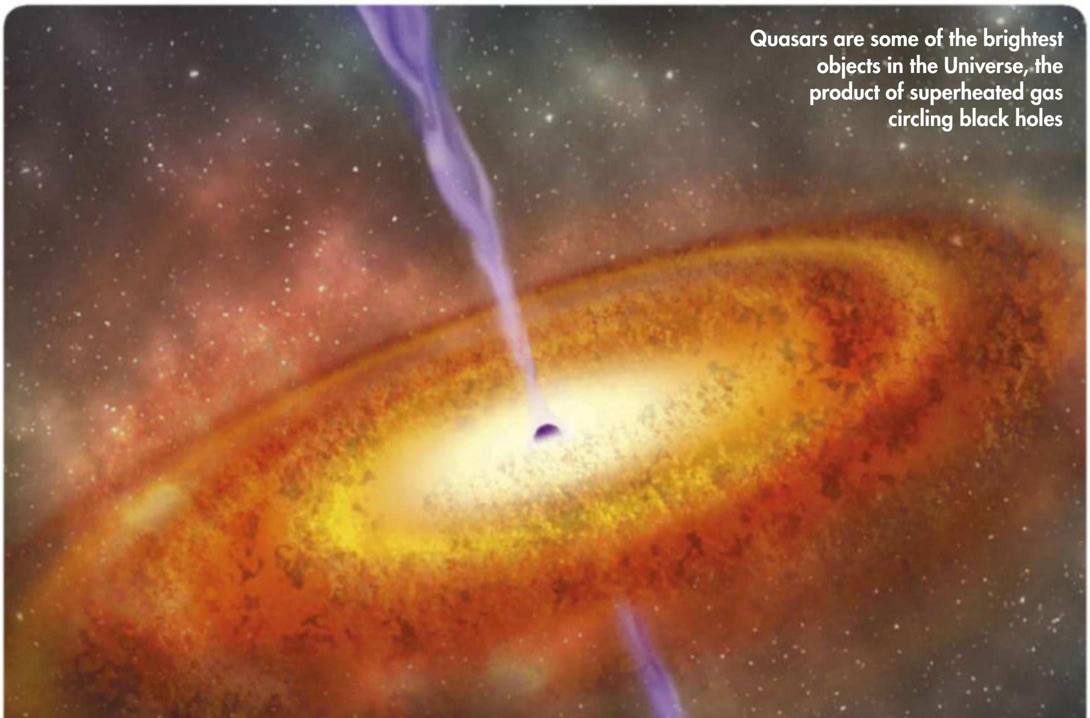
NEW HORIZONS DOUBLES UP

The next target for the New Horizons spacecraft, Kuiper Belt object 2014 MU69, could have a moon. The SOFIA flying observatory watched 2014 MU69 as it passed in front of a distant star, revealing its rough outline and the potential moon.

"We really won't know what MU69 looks like until we fly past it, or even gain a full understanding of it until after the encounter," says New Horizons team member Marc Buie. "But even from afar, the more we examine it, the more interesting and amazing this little world becomes."

'OUMUAMUA IS NATURAL AND ORGANIC

Interstellar asteroid 'Oumuamua, which sped through our Solar System in mid-October 2017 and was the first such visitor ever detected, is completely natural. New observations show that it is covered in a layer of organic material, which is most likely blanketing an icy core. Telescopes looking for radio emissions from the rock failed to find any radio signals that might suggest it was created artificially.



Quasars are some of the brightest objects in the Universe, the product of superheated gas circling black holes

BLACK HOLE IS A BIG BABY

The huge object has grown far faster than scientists can explain

An enormous supermassive black hole dating from the early Universe has recently been detected, and its far larger than can currently be explained. Light from the black hole dates back to 690 million years after the Big Bang, but the object is 800 million times as massive as the Sun.

"This is the only object we have observed from this era," says Robert Simcoe from the Massachusetts Institute of Technology. "It has an extremely high mass, and yet the Universe is so young that this thing shouldn't exist. The Universe was just not old enough to make a black hole that big. It's very puzzling."

The black hole dates from a time when the Universe was undergoing a great shift, in a process known as reionisation. The early Universe was dominated by neutral hydrogen, with electrons bound to the atomic nuclei. But as the first stars began to shine, their light ionised the gas, knocking electrons off the hydrogen atoms and creating the state of hydrogen in today's Universe.

The light from the black hole indicates that at the time it was emitted the Universe was half ionised, half neutral.

"This adds to our understanding of the Universe at large because we've identified that moment of time when the Universe is in the middle of this very rapid transition from neutral to ionised," says Simcoe. "We now have the most accurate measurements to date of when the first stars were turning on."

The black hole was spotted across multiple sky surveys while the team were looking for quasars, some of the brightest objects in the Universe. The light of quasars is created by gas circling around a black hole so fast that it superheats, causing it to glow intensely.

However, to create a quasar this bright requires a black hole that must be huge, and astronomers cannot currently explain how such a gargantuan object was created so soon after the Big Bang.

"If you start with a seed like a big star, and let it grow at the maximum possible rate, and start at the moment of the Big Bang, you could never make something with 800 million solar masses – it's unrealistic," says Simcoe. "So there must be another way that this formed. And how exactly that happened, nobody knows."

http://web.mit.edu

ROBIN DIENEL/CARNEGIE INSTITUTION FOR SCIENCE, NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE/STEVE GRIBBEN), GABRIEL PÉREZ, SMM (IAC), NASA/AUBREY GEMIGNANI, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA, JON WADE

NASA to return to the Moon

The move will be a jumping point for further exploration

The US is to return to the Moon, following a new space policy directive signed by President Trump on 11 December 2017. The funds for this aim are expected to be reflected in NASA's 2019 budget.

"The directive I am signing today will refocus America's space programme on human exploration and discovery," said US President Donald Trump. "It marks a first step in returning American astronauts to the Moon for the first time since 1972, for long-term exploration and use. This time, we will not only plant our flag and leave our footprints – we will establish a foundation for an eventual mission to Mars, and perhaps someday, to many worlds beyond," the President announced.
www.nasa.gov

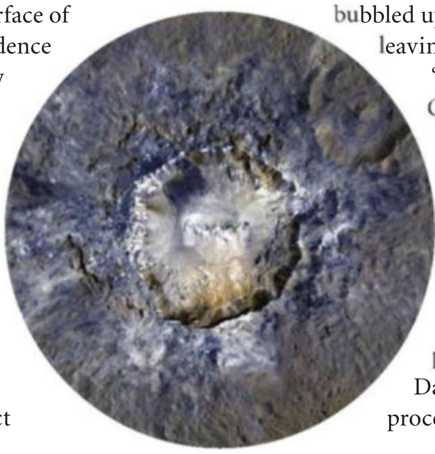
The US President signed the directive on 11 December – the anniversary of Apollo 17

Oceanic origins for Ceres spots?

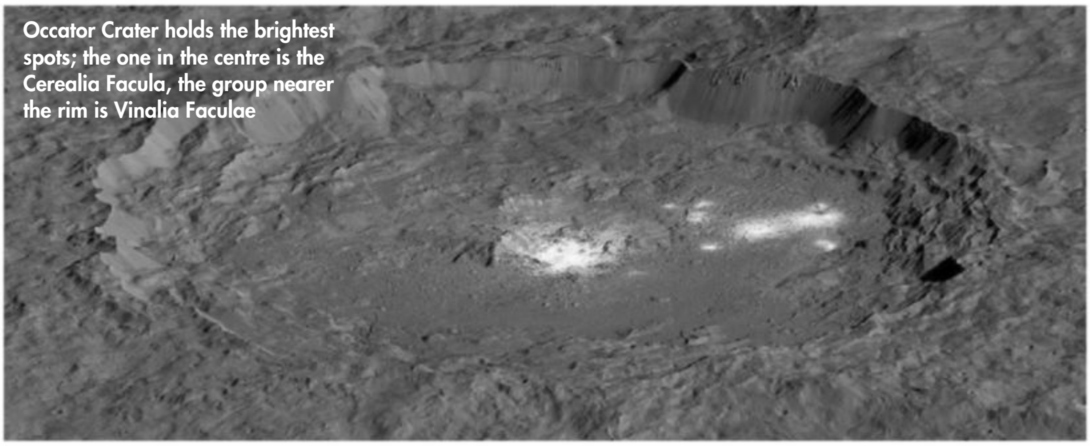
Bright spots seen all over the surface of dwarf planet Ceres could be evidence of a past subsurface ocean below the icy crust, according to the latest interpretation of images from the Dawn spacecraft.

The bright spots were first seen when Dawn entered orbit around the dwarf planet in March 2015. They are believed to be patches of salt on the surface, and this latest evidence suggests that they originated when a meteor impact created fractures in Ceres's crust through which salt water from an underground ocean bubbled up. The water then boiled away leaving the bright deposits behind.

"The mysterious bright spots on Ceres, which have captivated both the Dawn science team and the public, reveal evidence of Ceres's past subsurface ocean, and indicate that, far from being a dead world, Ceres is surprisingly active," says Carol Raymond, deputy principal investigator of the Dawn mission. "Geological processes created these bright areas and may still be changing the face of Ceres today."
https://dawn.jpl.nasa.gov



▲ Haulani Crater, which contains one of the bright spots later found to be a type of salt



Occator Crater holds the brightest spots; the one in the centre is the Cerealia Facula, the group nearer the rim is Vinalia Faculae

NEWS IN BRIEF

WHERE DID THE WATER GO?

A new geology experiment may have uncovered where Mars's water went – into the rocks, which absorbed it. Mars was once a much wetter place, but most of its moisture was either swept away by solar winds or frozen into subsurface ice. Yet there is still a large fraction of lost water unaccounted for. Now researchers examining the planet's minerology have found that Martian rocks held 25 per cent more water than similar geology on Earth, and are likely to have sucked up the missing liquid.

WHERE ARE ALL THE STARS?

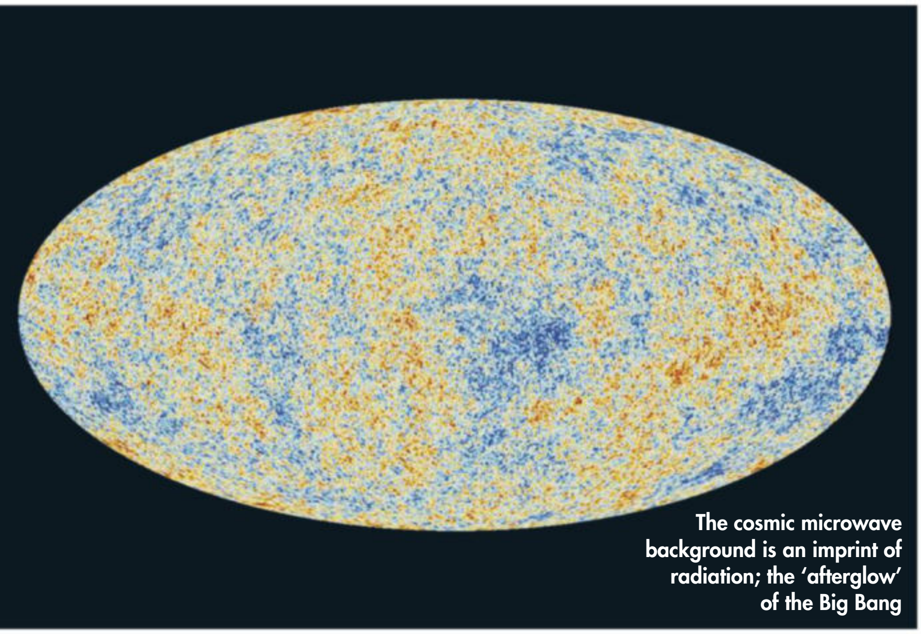
The formation of stars in the heart of galaxies could be slowed down by magnetic fields, according to research based on infrared observations of galaxies. In the Big Bang model, stars in the cores of galaxies should have formed at such a prodigious rate that all the gas should have been used up. As this is not the case, something must be halting the growth. A new theory suggests that as the gas collapses under gravity, the magnetic field pushes against gravity, slowing star formation.

CUTTING EDGE

Our experts examine the hottest new research

Easing the tension out of the Universe

Astronomers are trying to resolve the conflict between local and pan-Universal observations



The cosmic microwave background is an imprint of radiation; the 'afterglow' of the Big Bang

Modern cosmologists have a difficult time of it. Thanks to 30 years or more of hard observational work, their freedom to create new Universes, each one more complex and interesting than the last, is severely curtailed. Any model they build has to match observations on a wide range of scales, producing sensible galaxies and explaining the whole Universe, from the near-beginning of its story to the present day.

It's a complex jigsaw, so it's little wonder that the community jumps on any sign that the picture doesn't quite fit together. There don't seem to be any obviously missing pieces just yet, but there are a few places where things aren't as simple as they could be. For example, those who study galaxies and those who use data from ESA's Planck satellite to study the cosmic microwave background disagree on the value of Hubble's constant, which measures the rate at which the Universe is expanding.

Another source of 'tension' (the word physicists use for differences that aren't stark, but which won't go away) is examined in a new paper by Ian McCarthy of Liverpool John Moores University and colleagues. They compare observations of the cosmic microwave background with those of the cosmic web of galaxies in the local Universe. Each is sensitive to both the total amount of matter in the Universe, a quantity known as 'Omega_M' and how clumpy the arrangement of that matter is, captured in a measurement known as 'sigma_8'.

There are lots of different observations that can produce measurements of these numbers, which are related to each other. A Universe with more matter is one in which gravity plays a more important role, and therefore one which will be lumpier. Measurements taken by looking at local galaxies seem to favour lower values of both than measurements that look at the cosmic microwave background, whereas if all is well they should agree.

The authors are the first to point out that estimating the potential measures in each of the measurements is difficult, and it's certainly possible that the 'tension' could be resolved by correcting either set slightly. The approach here is different, though; using the wonderfully named BAHAMAS simulations, they investigate how to change the Universe to better agree with the observations.

"There don't seem to be any obviously missing pieces yet, but there are a few places where things aren't as simple as they could be"

The results are surprising. The team found that fixing the details of the recipe that controls the simulation doesn't help, but allowing neutrinos to have a more substantial mass than normally assumed really does. The spread out mass of neutrinos in simulations of the Universe normally helps to smooth out clumpy structures. But adding mass makes them more significant. We know that neutrinos can't be completely massless, but the simulations suggest they're about three times heavier than otherwise assumed.

This is an exciting result. The kinds of masses needed are allowed by our current understanding of particle physics, and it may be that the subtle differences in cosmological observations are telling us something profound about these tiny particles. Sometimes, if you want to understand the very small, you have to think big.

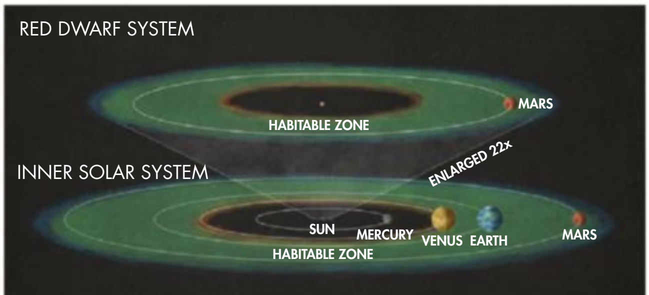
CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

CHRIS LINTOTT was reading… *The BAHAMAS project: the CMB – large-scale structure tension and the roles of massive neutrinos and galaxy formation* by Ian G McCarthy et al

Read it online at https://arxiv.org/abs/1712.02411

Mars probe offers exoplanet clues

MAVEN data hints at how long other worlds retain their atmospheres



Mars would have to orbit closer than Mercury to receive the same amount of light from a red dwarf as it does from the Sun

Observations made by NASA's MAVEN orbiter at Mars could help exoplanet researchers understand the atmospheres of distant exoplanets.

MAVEN has gathered a substantial amount of data about how the Martian atmosphere is lost due to effects of the Sun's radiation. From this, scientists have theorised how long a Mars-like world would remain habitable if it were orbiting a red dwarf star. Not as long, is the answer.

They suggest that such a world would be irradiated with five to 10 times more ultraviolet light than Mars, and this extra radiation would accelerate atmospheric loss. If the star was 'quiet' the planet's window of habitability could be shortened by five to 20 times; around an 'active' star the period could be reduced by a staggering 1,000 times.

"These estimates demonstrate one way to leverage what we know about Mars and the Sun to help determine the factors that control whether planets in other systems might be suitable for life," says Bruce Jakosky, MAVEN's principal investigator.
www.nasa.gov/maven

A hint of dark matter in Perseus

▲ The Perseus Galaxy Cluster, source of the mystery emission line, seen in X-ray and visible light

New interpretations of X-ray emissions from the Perseus Cluster could hint at the nature of dark matter.

In 2014, several X-ray scopes, including Chandra and XMM-Newton detected a spike in the intensity of light coming from the cluster at a specific energy – 3.5 kiloelectron volts (keV). Yet when Japanese satellite Hitomi observed the cluster in 2016, it didn't find anything unusual.

Researchers recently rexamined the cluster, and they found the 3.5 keV line was present in gas around the black hole at the heart of the cluster, but absent in the black hole region itself. Why the discrepancy? It could be dark matter which, they say, could have two energy states separated by 3.5 keV. The emission could be a sign of dark matter flitting between them.
http://chandra.si.edu

LOOKING BACK THE SKY AT NIGHT

February 1981

On 8 February 1981, Sir Patrick Moore invited two amateur astronomers onto *The Sky at Night* to talk about their recent astronomical discoveries.

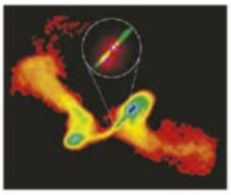
Dave Branchett was one. He was conducting a variable star survey on 18 January 1981 when he saw a new point of light in the constellation of Scutum. The find was later confirmed by the Royal Greenwich Observatory at Herstmonceux. At first Branchett thought he had discovered a nova or new star, but the star changed too rapidly. Even today, it is still uncertain what the object really was.

The second was Roy Panther, who had visually discovered the comet C/1980 Y2 with his homemade Newtonian. It was Panther's first comet, even though he had been looking for one since 1947, amounting to over 600 hours of search time.

"Discoveries of this kind are not sheer luck," said Patrick in the show. "I think it was really a magnificent piece of work."

▲ Patrick chats with Roy Panther (right) and Dave Branchett on the show

NEWS IN BRIEF



BLACK HOLE DOWN

Gravitational waves might not be as common as first thought, according to a recent study. Although astronomers thought that they were produced during the creation of winged radio galaxies, new research showed that this is not always the case. The galaxies were believed to be one of the major sources of gravitational waves, so it is likely that the total number is significantly lower than had been previously supposed.

DISTANT STARS TRACKED

The proper motions of stars in a small galaxy other than the Milky Way have been measured for the first time. Though astronomers have been able to measure the line-of-sight motion of stars for years, their motion across the sky (proper motion) has remained difficult to ascertain. By combining data from the Hubble Space Telescope and the Gaia mission, the team measured the proper motions of 15 stars. The measurements are important for testing our knowledge of how galaxies function.

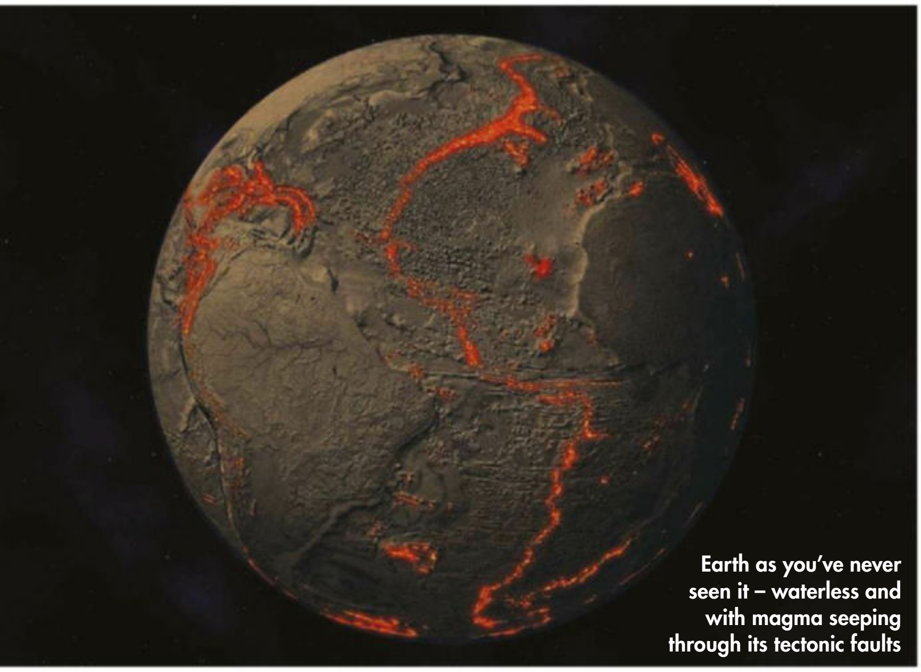
NRAO/AUI/ STSC, ESO/J. EMERSON/VISTA/ CAMBRIDGE ASTRONOMICAL SURVEY UNIT, NASA'S GODDARD SPACE FLIGHT CENTER, NASA/CXC/SAO, NASA/CXO/OXFORD UNIVERSITY/J. CONLON ET AL./NRAO/AUI/NSF/UNIV. OF MONTREAL/GENDRON-MARSOLAIS ET AL./NASA/ESA/IOA/A. FABIAN ET AL.; DSS, BBC

CUTTING EDGE

Our experts examine the hottest new research

If there's smoke, are there tectonics too?

It could be possible to trace tectonic plates on exoplanets by looking for erupting volcanoes



Earth as you've never seen it – waterless and with magma seeping through its tectonic faults

Earth is the only planet we know so far that has plate tectonics. Our planet's crust is fractured into discrete jigsaw pieces that are constantly gliding around the surface, colliding together or slipping beneath one another in a process called subduction. On the other hand, the other rocky planets in the Solar System have only single, stagnant crustal lids. Traditionally it's been thought that there's one key reason why a planet experiences plate tectonics: that the breaking stress of the thin crust must be exceeded by the forces exerted on it from beneath thanks to the convecting, gloopy mantle. This fractures the crust into pieces and drives their movement.

There's another effect that could be important for many exoplanets, however, say John Zanazzi of Cornell University in the US and Amaury Triaud of the University of Birmingham in the UK. For the first time, they have considered how the tidal forces caused by the intense gravitational pull on an exoplanet orbiting closely around its star would add to the stress created by its own mantle convection, and so make a fractured crust and plate tectonics more likely. They have built a simple computer model of such exoplanets and used it to calculate the tidal stresses they are likely to experience. And they found that the tidal effect is indeed significant enough to help trigger plate tectonics.

ISTOCK

LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

This may well turn out to be crucial for planets that have been discovered in habitable orbits around M-class dwarf stars – like those around TRAPPIST-1. The action of plate tectonics, and the control it exerts on carbon dioxide levels in the atmosphere, has regulated Earth's climate over hundreds of millions of years. But, as Zanazzi and Triaud are quick to point out, it might be possible to confirm these calculations.

There are two ways that telescopic observations of exoplanets could provide evidence for the operation of plate tectonics on a remote exoplanet. Volcanism on any silicate, rocky world releases large volumes of gases, such as sulphur dioxide. Volcanoes are especially prevalent on Earth along the zones of plate subduction (such as the Ring of Fire, all around the Pacific Rim), and particularly explosive 'Plinian-type' eruptions inject these gases very high

"Spectroscopic observations of an exoplanet's atmosphere could reveal the presence of such volcanic gases"

into the atmosphere. Spectroscopic observations of an exoplanet's atmosphere could reveal the presence of such volcanic gases.

But perhaps even more excitingly would be the possibility to actually map the location of active volcanoes on the surface of an exoplanet. For some exoplanets in a convenient orientation from Earth's viewpoint, we can observe their light as they orbit behind their parent star. Their surface becomes progressively eclipsed, and so by accurately measuring how the planet's light changes over time it's possible to build up two-dimensional maps of their surface. The hot lava exposed in active volcanoes is conspicuous at mid-infrared wavelengths and so Zanazzi and Triaud predict that the James Webb Space Telescope might be able to map the locations of a nearby exoplanet's volcanoes.

Just as with most volcanoes on Earth, if the planet had tectonics these would follow the outlines of the subducting plates.

LEWIS DARTNELL was reading… *Initiation of Plate Tectonics on Exoplanets with Significant Tidal Stress* by JJ Zanazzi and Amaury Triaud
Read it online at https://arxiv.org/abs/1711.09898

Make the dream of having your own observatory reality

Many amateur astronomers would love to have their own observatory. Your telescope then no longer has to be moved and remains ready for immediate use at any time. The dome protects the telescope from stray light, wind and weather.

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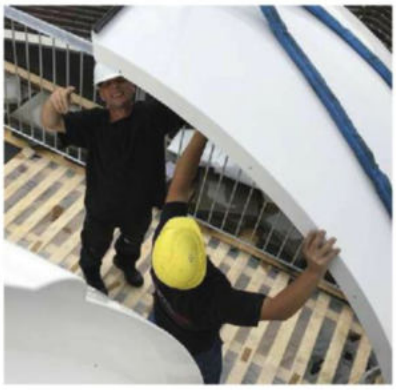
We offer everything from a single source: telescope, dome and complete set-ups – we are looking forward to hand your own private observatory over to you – complete and ready to use!





Our customers include not only experienced amateur astronomers, but also clubs, schools, universities and other institutions - in many countries in Europe and worldwide.

> You can see some of our reference projects at www.astroshop.co.uk/observatories

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What's on

Our pick of the best events from around the UK

PICK OF THE MONTH

▲ This year's festival promises adventure and dark skies in equal measure

Yorkshire Dark Skies Festival 2018

Yorkshire Dales and North York Moors National Parks, 9-25 February

Celebrate the dark skies of Yorkshire as the Yorkshire Dark Skies Festival returns for its third year, with stargazing events occurring across two national parks. This year's festival has been expanded from nine to 17 days and features over 50 events suitable for all ages.

Each National Park has three Dark Sky Discovery locations – places where the skies are dark enough to view the Milky Way with the naked eye on clear nights. Visitors to this year's festival can enjoy an evening's stargazing against the backdrop of some of North Yorkshire's most historical landmarks, and a celestial safari in the Yorkshire Dales takes stargazers on a tour of the grounds of Bolton Castle, led by an experienced astronomer.

Young astronomers can get crafty making rockets, telescopes and planet lanterns, and are invited to join Forest Schools on a night-time walk for some stargazing and lessons on woodland skills. Thrill-seekers can enjoy a nighttime zip wire experience taking them more than 200m into the dark Dalby Forest. There will also be opportunities for caving, cycling, walking and running under the night sky.

A number of events are free, but some have an admission fee. Go online for a full programme, dates and prices.
www.darkskiesnationalparks.org.uk

BEHIND THE SCENES

THE SKY AT NIGHT IN FEBRUARY

BBC Four, **11 February,** 10pm (first repeat BBC Four, **15 February,** 7.30pm)*

Interstellar asteroid 'Oumuamua is a rocky, elongated object – perhaps as long as 400m

IT CAME FROM OUTER SPACE

Last year, the Solar System received an unusual visitor: an elongated asteroid since named 'Oumuamua. This body came from interstellar space, making it the first such object ever observed. *The Sky at Night* reveals what we know about 'Oumuamua, and how it is changing our view of the Universe.

**Check www.bbc.co.uk/skyatnight for subsequent repeat times*

The Early Universe

Great Ellingham Recreation Centre, Attleborough, Norfolk, 9 February, 7.30pm

First a Big Bang. But what next? Billions of years later, the early Universe is being uncovered using supercomputers and observations of the first galaxies. Are we humans a way for the Universe to study and understand itself? Dr Sarah Bosman of University College London presents this talk on the early Universe for Breckland Astronomical Society. Admission is £2 for adults and £1 for children.
www.brecklandastro.org.uk

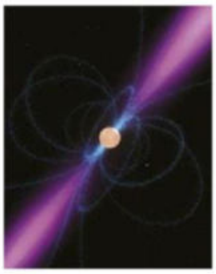
The Story of the Solar System

Redgrave Theatre, Bristol, 24 February, 7.30pm

Astronomer and *BBC Sky at Night Magazine* writer Will Gater tells the story of the birth of the planets, moons, asteroids and comets orbiting our Sun. Featuring live demos and a history of space exploration from early astronomy to robotic rovers, this is a lively tale of how our cosmic neighbourhood came to be. Tickets are £12, or £10 for concessions. To book tickets, visit the event website.
willgater.com/solarsystem

The Secret Life of Pulsars

Ballyclare High School lecture theatre, County Antrim, 5 February, 8pm

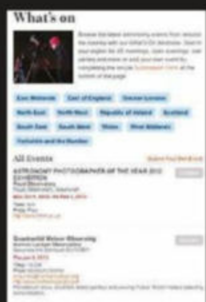


February marks 50 years since the announcement of the discovery of pulsars by Jocelyn Bell Burnell and Anthony Hewish. In this talk for the Northern Ireland Amateur Astronomy Society, Dr Rene Breton of the University of Manchester looks back on the last five decades of research into these incredible cosmic lighthouses. The event is free; visit the society's website for more info.
www.eaas.co.uk/cms

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

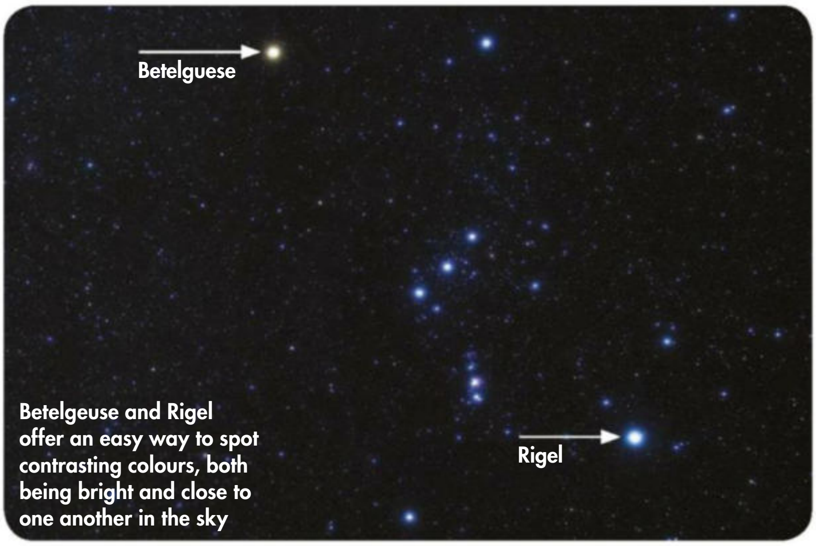
To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.



A PASSION FOR SPACE

with **Dr Jen Gupta**

Why are some stars red, and why are some blue? It's an exciting story, says astrophysicist Jen Gupta



Betelgeuse and Rigel offer an easy way to spot contrasting colours, both being bright and close to one another in the sky

Take a quick glance up at the night sky and you can be forgiven for thinking that it only exists in black and white, with distant stars appearing as pinpricks of white light against a dark background. But look a bit closer and even with the naked eye, you'll start to see that the Universe is awash with colour.

At this time of year, my favourite sight on a clear night is the familiar constellation of Orion, and it's within this pattern of stars that we can see a classic example of colours in the night sky. Look carefully at the star Betelguese – Orion's right shoulder (assuming he's facing us) – and you'll notice that it has an orange-red tinge to it. Compare this with the star Rigel, on Orion's left foot, and you'll see that Rigel appears much more blue-white.

The reason these stars look different colours is all to do with their temperatures. It's the opposite to what you might initially think, because red stars like Betelguese are actually cooler than blue stars like Rigel. I say cooler, but bear in mind that the surface temperature of Betelguese is still around 3,200°C, compared to Rigel's 10,700°C. This may seem counterintuitive based on our everyday experiences of linking colour to temperature (think colour-coding on taps: red for hot and blue for cold) but it's the same principle as when metal is heated in a forge – first you'll see it start to glow red, then as its temperature increases the metal glows a blue-white.

Atomic influences

A pair of binoculars or a telescope can reveal even more colour. Sticking with Orion, a small telescope will reveal that the fuzzy 'star' in the middle of his sword is not a star at all, but actually the Orion Nebula, a region where new stars are being born. Here the gas is being lit up by radiation from the young, newly formed stars, transferring energy to the atoms in the gas and 'exciting' them. Due to the different atomic structures of the elements in the Orion Nebula, we see different colours when we look at it through a telescope, including pinky-red from hydrogen and green from oxygen.

In fact, every element in the periodic table will emit a unique pattern of colours when excited, and this is the element's spectrum. In the same way as you can split white light up into a rainbow using a prism, splitting observed light up into its spectrum with a technique called spectroscopy allows astronomers to identify what elements are present within a nebula. One of the pioneers of this field of work was Margaret Huggins, an unsung hero of astronomy, who worked with her husband William in the late 19th century to catalogue the spectra of stars, galaxies and nebulae.

Today, spectroscopy is perhaps the most powerful tool in an astrophysicist's toolkit, enabling us to do everything from detecting exoplanets around distant stars, to measuring the expansion of the Universe, to inferring the existence of mysterious dark matter in galaxies. All this from analysis of the colours in the night sky. Ⓢ

ISTOCK

Astrophysicist Dr Jen Gupta is a regular contributor on *The Sky at Night*

Maggie Aderin-Pocock is on holiday

JON CULSHAW'S

EXOPLANET EXCURSIONS

Jon visits an Earth-sized world close to home with an unexplained mystery

Being in the mood for a gentle amble, I'm taking my ship, the Perihelion, for the astronomical equivalent of a saunter up a country lane – a neighbourly 11-lightyear trip Ross 128 in Virgo, the 12th-closest star to our Solar System. Ross 128 evokes a feeling of reassuring familiarity – it's 15 per cent of the Sun's mass and 20 per cent of its diameter. And around this small, red, M-class star there's an exoplanet that's thought to be the most suitable yet for supporting life.

The world of our visit on this occasion is Ross 128 b, a terrestrial planet 1.35 times the mass of the Earth. It's nestled close to its parent star at 0.0496 AU, very much at the warmer end of the system's habitable zone. A year here is a shade longer than an Earth week: it takes 9.9 days for the exoplanet to complete an orbit.

Setting down upon the surface of Ross 128 b, it becomes apparent that all prophecies of this world's habitability are wonderfully true. This is a warm and balmy place – quite a paradise in how it feels. The planet receives 38 per cent more light from its star than Earth does from the Sun and, as I've landed in the far north of the planet, the climate here is comparable to a humid Florida afternoon.

I park the Perihelion near the edge of a giant lake, which reflects the depth of redness from the home star. Planets like these, bathed in benevolent red starlight, are without doubt my favourites to visit. Ross 128 b is a particularly calm place to settle as the parent star is so quiet itself. Unlike Proxima Centauri, which lashes out with destructive solar flares, Ross 128 is gentle and uneventful. It's nice not to have to be on high alert for dangerous stellar radiation blasts.

The landscape is unfathomably bizarre. Rounded peaks are clumped together like haematite swells the size of Ben Nevis. The sides of these peaks facing the starlight are covered in what looks like an algal coating of bronze-coloured slime. Odd pockets of it appear to expand, like a tree frog inflating its chest. There are thousands of these features filling out and deflating all the way up these smoothed peaks. And the sound! Like tens of thousands of tubas being tuned up for a concert of every bass instrument in existence.

That's not the only odd phenomenon to occur on this planet. On 12 May 2017, researchers from the Arecibo Observatory in Puerto Rico picked up some very unusual radio signals. Two months later, on 16 July, another strange signal was detected. There have been none since.

I can't help but stare out over this weird landscape, wondering what could have generated those signals. Were they anomalies or equipment errors, or something else entirely? It feels oddly tense, as if at any moment a strange artificial shape is about to slip silently across the dark orange shine of Ross 128 and dim its light. The cosy climate and reassuring red starlight now carries the eerie sense of a *Quatermass* sequel.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*

MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

Interactive

EMAILS ◢ LETTERS ◢ TWEETS ◢ FACEBOOK

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philips: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *2018 Stargazing*.

Tales from THE EYEPIECE

Stories and strange tales from the world of amateur astronomy by Jonathan Powell

Sometimes, the grass seems greener when it comes to observing sites. Somewhere away from home may have the merit of a better horizon, or perhaps the site is simply darker. But, for one reason or another, these are forbidden fruits frustratingly out of bounds.

An astronomer friend of mine had one such place next door. One evening, when his neighbours were out, we decided to observe from a nicely concreted area right in front of the house. If you've ever assembled your telescope in less than favourable light, you'll know it's a skill that becomes second nature over the years. However, when you sight said neighbours returning to their house from across the lane, you'll find the de-assembling of a telescope can be done in mere seconds!

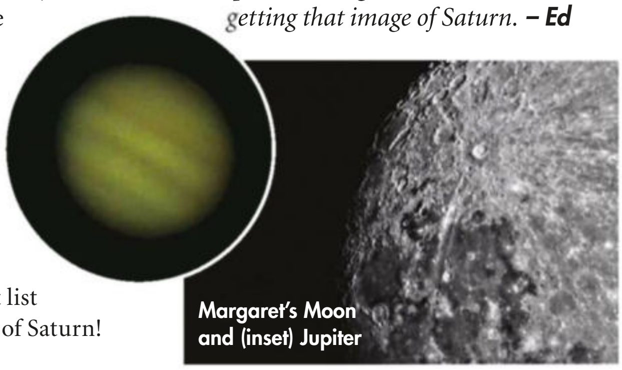
Jonathan Powell is the astronomy correspondent for the South Wales Argus

MESSAGE OF THE MONTH

A hobby for all ages

I love to see all the photos you show in the magazine each month, especially the ones from youngsters. I am at the opposite end of my life, at nearly 80 years old, and I acquired my first Canon DSLR camera less than a year ago. This is my first attempt to take photos of Jupiter and the Moon using eyepiece projection photography. On my bucket list this year is to take a picture of Saturn!

Margaret Grove, via email



Margaret's Moon and (inset) Jupiter

Fantastic to see such impressive early astrophotos, Margaret! Good luck getting that image of Saturn. **– Ed**

Full of doubt

I am a newcomer to the magazine, and I am enjoying it. I do have a minor grumble, though in fairness this is something that has been brewing for far longer than I have been a reader, so please forgive me aiming it in your direction. One of the things often written when new discoveries are made is that they 'could throw Einstein's theories into doubt'. This is far milder than the oft-recited notion that Einstein will be 'proven wrong'. I think this is scientifically unrepresentative: all theories are simply our best models, and periodically require tweaking or expanding. Seldom are they thrown out wholesale or proven fallacious, they are merely adapted to suit subsequent observations. After a century, and in all but the most extreme environments, Einstein's theories would still be 'right' enough to model the Universe. After all, without relativistic effects Newton is still 'right' in almost all scenarios!

Simon Bartlett, via email

You're quite right, Simon. Most scientific theories are approximations to explain our current knowledge of the Universe, so 'proving a theory wrong' is the same as finding a new circumstance where it no longer applies. **– Ed**

Tweets

Mark Forbes
@SCN_ZBOYD • Dec 11
Messier (M45) The Pleiades open star cluster. 45x1minute exposures @ ISO1600 stacked. @altair_astro 102ED refractor + x0.8 reducer. @CanonUKandIE EOS750D @skyatnightmag @BBCStargazing #Stockport #Manchester

Outside influence

Is there a possibility that dark energy turns out to be nothing more than gravity? We have no idea what exists outside the visible Universe and if it turns out that much more mass exists outside the visible

SOCIETY in focus

▲ **Dedicated to helping all astronomers, the SPA hosts regular meetings and outreach sessions**

The Society for Popular Astronomy (SPA) is marking its 65th anniversary with a new-look website – **www.popastro.com**. It's a resource for experienced astronomers and beginners alike, with guides on stargazing, taking your first glimpse through a telescope, selecting scopes and binoculars, and getting started in astrophotography.

It also includes an astronomical glossary, so wherever a technical term crops up you can easily find out its meaning. The new website is accessible via a desktop computer, tablet or smartphone. And, if you would like to get involved in the society, SPA holds four meetings a year, taking place in the historic Gustave Tuck Lecture Theatre at University College London.

We really want to help all beginners to astronomy, and the help files on our website will give a good start to anyone who wants to get into the subject.

Robin Scagell
President of the Society for Popular Astronomy
www.popastro.com

Universe than exists within it, then the Universe's behaviour (its continual expansion at ever increasing rates as it gets farther out) could be accounted for by the gravitational attraction of this outer mass. The 'Massiveverse' would be a good name for all of this possible external mass, and it would make the theory of dark energy redundant. Since the visible Universe appears to be expanding in every direction at once, the Massiveverse would have to be homogeneous in mass and totally surround the visible Universe.

Mike Reynolds, Chesterfield

A very interesting theory, Mike. As well as dark energy there are several competing theories as to the cause of the Universe's expansion, and many who think the acceleration is a mistake in the first place! ***– Ed***

Meteor magic

I often receive your magazine from a friend and be sure that I like it a lot. As a scientific guy and watercolour artist I paint some of my astronomical observations. This is my latest one, of the Geminids on the morning of 13 December. Everything was done from, or close, to the Verdon Regional Natural Park in France, where I live. I hope this approach is interesting for UK readers. Keep up the good work!

Michel Deconinck, Artignosc-sur-Verdon, France

Your watercolour really captures the magic of observing a meteor shower on a clear, dark night, Michel. Thanks! ***– Ed***

Tweets

mmcneillphotography
@marksmcneill • Nov 8
Caught this over Beacon Fell last night in Lancashire @Learntoskywatch @ROGAstronomers @RMetS @apod @VirtualAstro @ProfBrianCox @skyatnightmag @AstronomyMag @Stephencheatley

Meanwhile on FACEBOOK...

WE ASKED: What would the conditions be like on your ideal exoplanet?

Paul Beach
It has several mountains for skiing in winter but for the rest of the year it is a pleasant 20°C. For uninterrupted stargazing, clouds form only during the day, and when it rains it rains beer.

Shareen Ismail
Completely inhospitable for human life.

Lynda Woodhouse-Hall
Warm, 27°C during the day, clear skies at night for stargazing and rain between 3am and 6am, for the plants.

Simon Whitfield
My ideal exoplanet would be close enough to study it extensively, but far enough away we could never reach it.

William Wickham
No light pollution with clear night skies.

Martin Holroyd
Like Yorkshire.

Katie Eloise Kalani
What Martin said :-).

Al Higgs
Not too warm, not too cold. Several moons for observing and lots of dark skies for stargazing.

James Gill
Summer Sun during the day; storms during the night and it always snows on Christmas.

Wayne Ryles
Lovely spring sunshine all year round, with a California blue sky with limited rain, and plenty of clear nights for stargazing.

Martin Donaghy
No humans.

Joan Williamson
Crystal clear skies, comfortable temps, an exceptional view of our Solar System and a wonderful meteor shower.

Amanda Large
An exoplanet exactly like Earth, but where all the humans were more interested in not harming the planet.

Will Sneddon
Canada. Basically Canada in exoplanet form with no human light pollution.

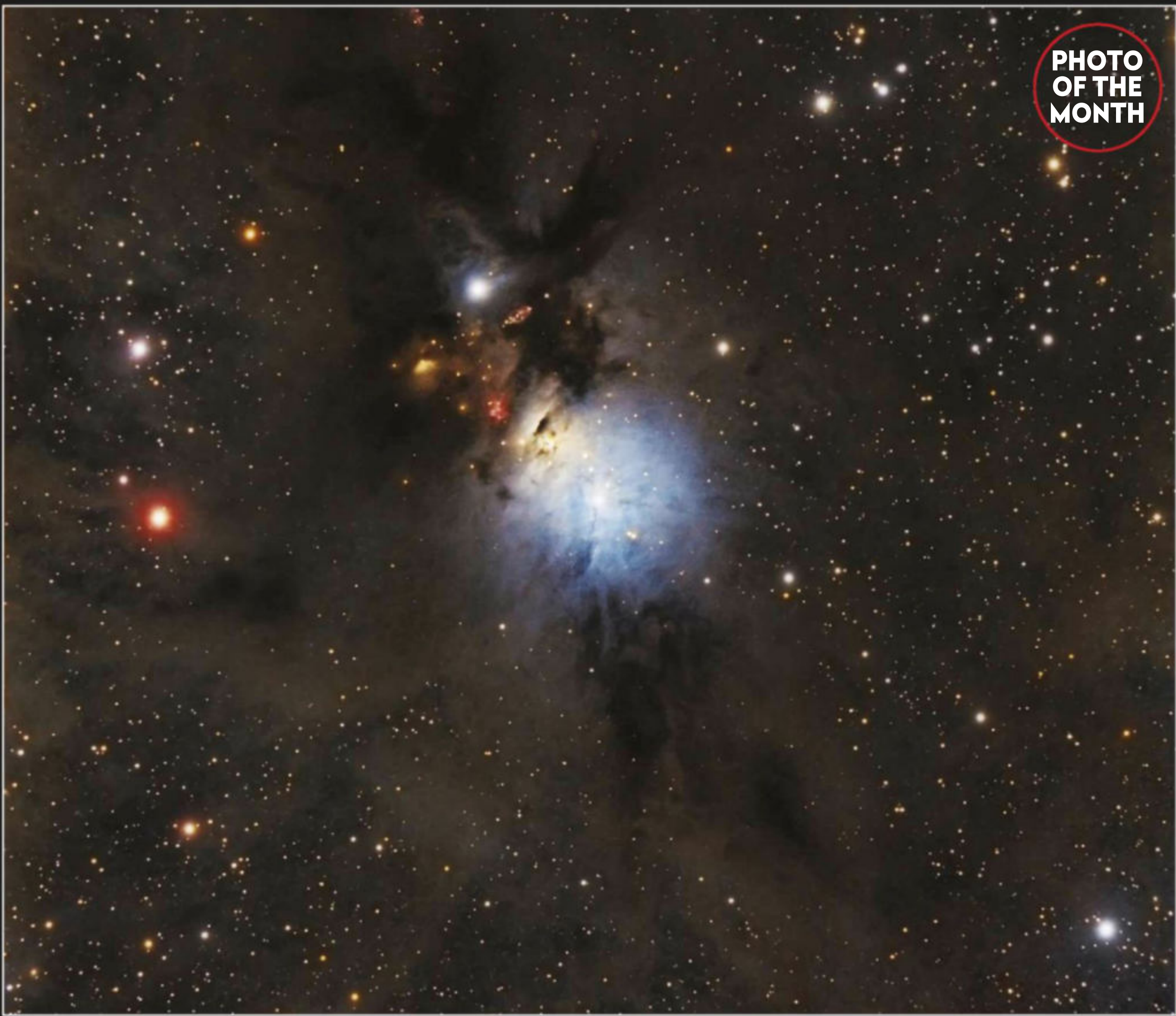
Jordan Tyldesley
Two days sunny, one day rain all year round. Never goes below 15°C.

Hotshots

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images

This month's pick of your very best astrophotos



▲ NGC 1333

DIDIER REDIGER-LIZLOV/DAVID ATTIÉ/STEFAN SHRAMM/E-EYE REMOTE TELESCOPE HOSTING SERVICE, SPAIN, 25-30 OCTOBER 2017

David says: "For the first light of our remote observatory in Spain, we were looking for a target that would show the difference between a mobile setup under a light-polluted sky and a permanent setup under a good one. We voted for NGC 1333, as it was the perfect time of year to image this object. We made 33 hours of acquisitions, operating from Abu Dhabi and Paris."

Equipment: Two Moravian Instruments G2-4000 CCD cameras, Altair 130 ED Triplet apo refractor, GSO 8-inch Dobsonian, Astro-Physics 900 GTO German Equatorial Mount.

***BBC Sky at Night Magazine* says:** "We love elaborate and well-oiled imaging projects, and this certainly fits the bill. The coordination involved is staggering, and justified given that the result is so impressive."

About the team: "In July 2017 we flew to Spain and spent four days installing everything at e-Eye, a remote telescope hosting service. Stefan is German, currently in a postdoctoral contract in Abu Dhabi. David is a French Air Force officer, currently assigned to Abu Dhabi. Didier is retired (almost!) and lives in Paris. We all share the cost. We do everything remotely and in case of emergency, someone lives close by!"

◀ Star trails

PEDRO LUIS CUADRADO, LAS INVIERNAS, GUADALAJARA, SPAIN, 18 NOVEMBER 2017

Pedro says: "It's easy to capture traces of aircraft and their blinking lights. This was probably the biggest challenge in processing, as I had to manually erase these aircraft trajectories to leave a sky clear of human artefacts."

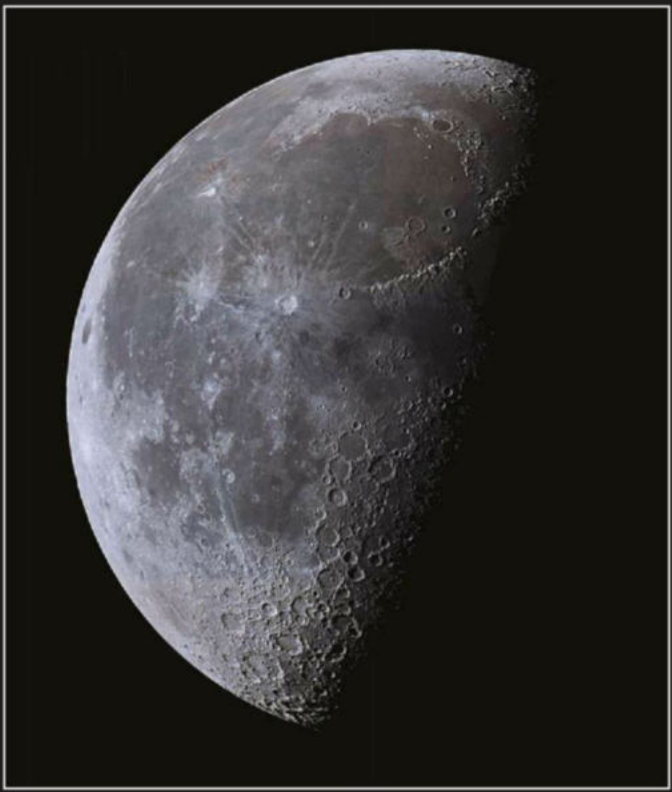
Equipment: Canon EOS 7D DSLR camera, Samyang CS 8mm lens.

▼ Moon montage

DAVID ETTIE, TYNE AND WEAR, 10 NOVEMBER 2017

David says: "I rose early as the forecast was for clear skies. Using a DSLR at prime focus on my scope, I took a series of movie files, splitting the lunar disc into north, south and middle. These were then processed using software and the final montage was assembled."

Equipment: Nikon D3200 DSLR camera, Celestron 9.25-inch Schmidt-Cassegrain.



▲ The Triangulum Galaxy, M33

GARY STONE, PETERBOROUGH, 18 NOVEMBER 2017

Gary says: "To capture M33 has long been a desire of mine. Due to the location of my garden, the window of opportunity for me to do so was always going to be narrow, with visibility of two hours maximum during the winter months. I was absolutely delighted with this final image and the amount of detail, all from a suburban back garden!"

Equipment: Canon EOS 450D DSLR camera, 10-inch Sky-Watcher Quattro imaging Newtonian, Sky-Watcher NEQ6 Pro SynScan mount.

◀ The Soul Nebula

DAN ORNSBY, SWINDON, 5 & 17 NOVEMBER 2017

Dan says: "I've always been a fan of the nebula and had previously only imaged it with my DSLR, with less than satisfactory results. Since upgrading to a CCD I've been revisiting a lot of targets."

Equipment: Atik 383L+ CCD camera, William Optics Star 71 refractor, Sky-Watcher NEQ6 Pro SynScan mount.

Skye aurora ▶

GILL WILLIAMS, ISLE OF SKYE, 7 NOVEMBER 2017

Gill says: "I can usually see good aurorae from my garden on Skye, but decided I wanted something a bit more atmospheric. I drove to the end of the peninsula and set up in Trumpan graveyard just as it was getting dark. It really was a spectacular show and worth the cold conditions. It lasted most of the evening so I didn't get a great deal of sleep!"

Equipment: Canon EOS 6D DSLR camera, Samyang 14mm lens.

◀ Orion's Belt

DAVY CANNON, HAMILTON, 19 NOVEMBER 2017

Davy says: "It was tricky to get all three belt stars of Alnitak, Alnilam and Mintaka in the frame and leave room for the Flame and Horsehead Nebulae. I got the image after lots of patience and high ISO test shots, which I used to help adjust the position of the scope and the rotation of the camera."

Equipment: Canon EOS 60Da DSLR camera, Altair Astro Starwave 70 ED triplet apo refractor, Sky-Watcher NEQ6 Pro SynScan mount.

◀ Venus, Jupiter and the Moon

ROGER SAMWORTH, NAILSTONE, LEICESTERSHIRE, 17 NOVEMBER 2017

Roger says: "I do a lot of imaging indoors from a telescope sitting on an upstairs windowsill. However, in this case a tree was obscuring the view, so I had to trek to the bottom of the garden in my dressing gown to get this picture!"

Equipment: Canon Powershot SX610 HS camera.

▼ The Bubble Nebula

JEFF JOHNSON, NEW MEXICO, US, 3 SEPTEMBER 2017

Jeff says: "This is my most recent processed result from data collected from my backyard. The image is LHaRGB, where hydrogen-alpha was used in combination with luminance; Ha:R (80:20) was used for the red channel."

Equipment: QSI 540wsg CCD camera, Takahashi TOA-130F refractor, Takahashi EM-200 Temma II mount.

▲ The Heart Nebula

JAMES ROBERTSON, CROYDON, 8 NOVEMBER 2017

James says: "After a very long run of cloudy nights, not even a full Moon could make me pass up a clear one! I did wonder how good the deep-sky results would be, but a narrowband hydrogen-alpha filter with my DSLR worked a treat."

Equipment: Modified Canon EOS 750D DSLR camera, Sky-Watcher Esprit 80 ED triplet refractor.

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SPARKLING DIAMONDS IN THE WINTER SKY

Astronomer **Will Gater** admires some of the exquisite star clusters on show during the chilly winter nights

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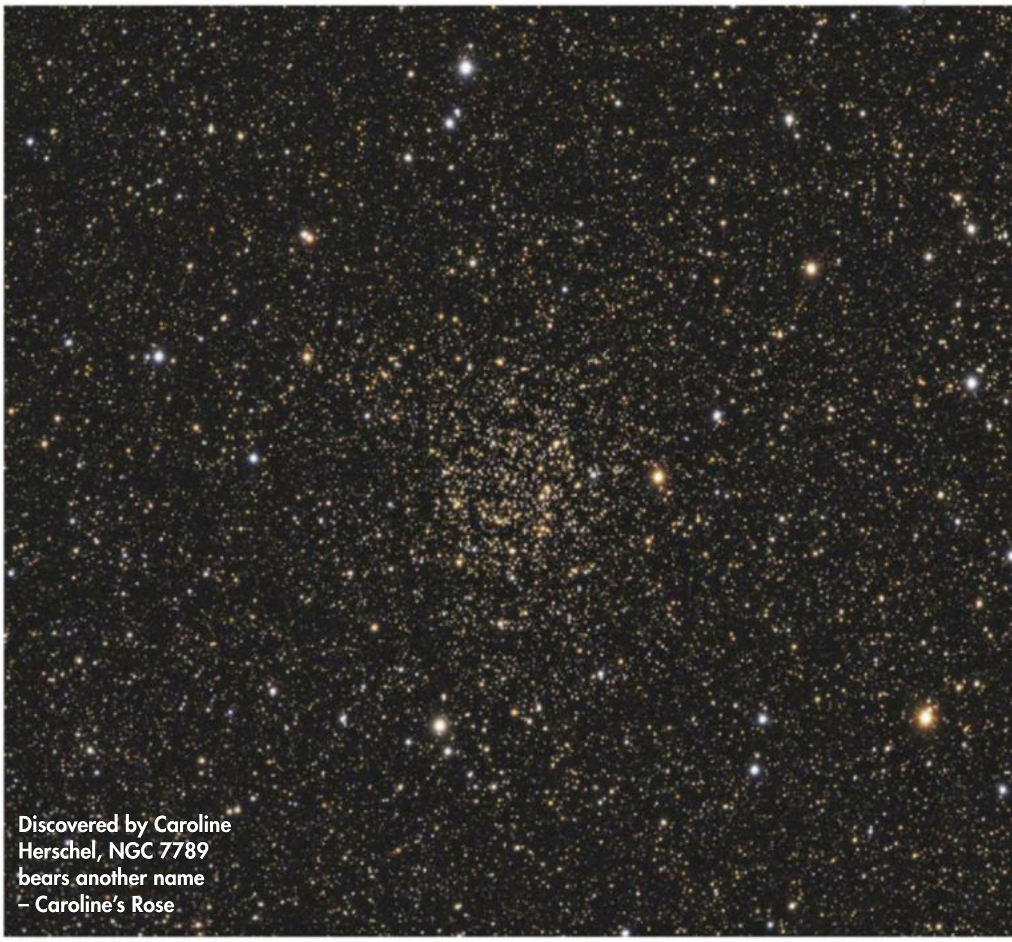
Winter observing is all about those incredibly cold nights when the transparency is so good that the stars look like brilliant points against an inky darkness that descends all the way down to the horizon. On those special evenings there are few things better than getting out the scope and turning it to some of the myriad sparkling star clusters that fill the winter sky.

On the following pages you'll find a tour of 12 of the season's best clusters – there are some favourites and some lesser-known ones. There should be something for every observer here: among the tour there are fine binocular targets, like the Pleiades, and perfect objects for small scopes, like M35, while some of the other clusters will require a larger aperture instrument to see well. You can start the tour right after darkness falls and carry on through the evening. So get those thermals on and wrap up warm, as together we go in search of some winter's glittering celestial gems.

ABOUT THE WRITER
Will Gater is an astronomy journalist, author and presenter. Follow him on Twitter at @willgater or visit willgater.com



Discovered by Caroline Herschel, NGC 7789 bears another name – Caroline's Rose

1 NGC 7789

We begin our tour in the constellation of Cassiopeia, which this month is over in the northwestern part of the sky as darkness descends. Our target is the open cluster NGC 7789. Through 10x50 binoculars the cluster looks like a faint patch of light midway between mag. +4.5 Rho (ρ) Cassiopeiae and mag. +7.0 Sigma (σ) Cassiopeiae; if you place mag. +2.3 Caph (Beta (β) Cassiopeiae) near the top of the field of view of a pair of 10x50s the cluster will be in the centre. Through an 8-inch scope, using a magnification of around 80x, the cluster appears as a smattering of stars that become more numerous with averted vision; to my eyes the cluster seems to dissolve into its surroundings towards its northeastern edge.

SEEN IT ☐

2 NGC 752

We're now going to start making our way roughly southeast across the sky in the direction of some of the more traditional winter constellations, but before we do let's stop off at the open cluster NGC 752 in Andromeda. It's fairly easy to find with a pair of 10x50 binoculars using mag. +5.3 star 7 Trianguli and mag. +3.0 Beta (β) Trianguli as 'pointers' to direct you northwest towards the cluster. You'll know you're in the right place as there's a conspicuous close pair of stars (mag. +5.7 56 Andromedae and mag. +5.9 HD 11727) very near the cluster. In an 8-inch telescope with a magnification of around 50x the cluster, with several gently curving arcs of stars, practically fills the field of view – a beautiful sight and a taster of more splendours still to come. ▸

SEEN IT ☐

▲ NGC 752 is a large, scattered star cluster

3 M34

► We don't have to go far for our next target, the open cluster M34, which sits just under 10º away in Perseus. In an 8-inch scope, using a magnification of roughly 50x, M34 is an exquisite sight, appearing as a collection of loosely scattered stars seemingly arranged in pairs. This is definitely a beautiful target for a wide-angle eyepiece. The cluster appears compact and bright in 10x50 binoculars. To find it in 10x50s at around 8pm this month, place the bright, mag. +2.1 star Algol (Beta (β) Persei) near the upper-left edge of the field of view; M34 will then be in the bottom right. Through binoculars several of the cluster stars are clearly visible with direct viewing, while a few more come into view with averted vision.

SEEN IT ☐

M34 is an excellent candidate for a wide-angle examination

M45 is also known as the Seven Sisters – though there are of course more than seven stars in the cluster

4 The Pleiades

From Perseus we hop into nearby Taurus and a truly spellbinding winter object, easily visible to the naked eye: the Pleiades. Also designated M45, it is arguably the most striking open cluster in the night sky. In most long focal length telescopes you'll struggle to fit it all in the eyepiece, and at 50x magnification the central region of the cluster simply appears as a spectacular field of blazing blue stars. For us, though, the Pleiades are made for binoculars, and through a pair of 10x50s from a dark-sky site they are a mesmerising sight, taking on an almost three-dimensional appearance. One of our favourite binocular details in the cluster is the curving chain of stars that runs from the vicinity of mag. +5.4 HD 23753 in the direction of mag. +2.9 Alcyone (Eta (η) Tauri).

SEEN IT ☐

5 Trapezium Cluster

If you can pull yourself away from the Pleiades, it's now time to move on to our next target, which lies across the border in Orion. The young Trapezium Cluster provides a very different view of an open star cluster compared to the others we've observed so far, because it's still embedded within, and surrounded by, the nebula from which it formed; the famous Orion Nebula, M42, which sits below Orion's Belt. The Trapezium is too small to resolve clearly in small binoculars, but in an 8-inch scope with a magnification of approximately 50-80x the view is breathtaking, with the cluster appearing as four points of light set at the tip of a dark 'finger' of nebulosity that extends into the bright inner part of M42.

SEEN IT ☐

The Trapezium forms the heart of the Orion Nebula

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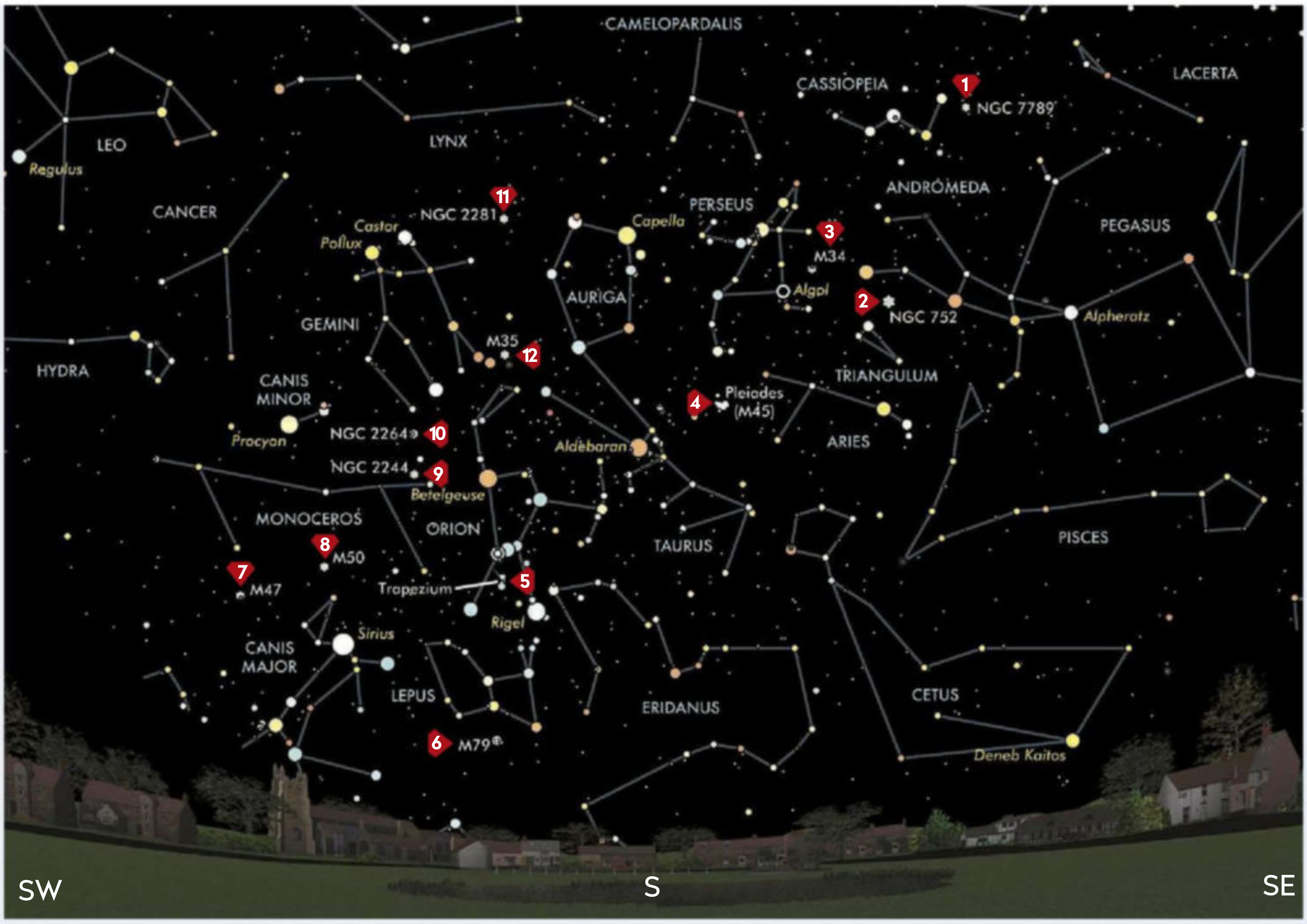
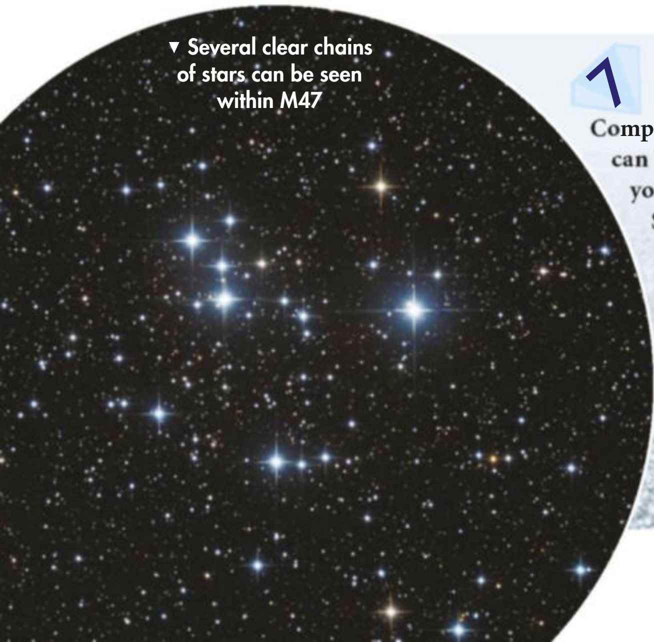


6 M79

We're now going to move almost due south by roughly 19°, towards the constellation Lepus. For UK observers, you'll immediately see that this takes us close to the horizon, meaning you'll need a clear southern view and transparent skies for this next cluster. The reason we've ventured in this direction is that our next target is a rarity in this part of the winter sky: a globular cluster, M79. It was too faint for us to see using 10x50 binoculars the last time we looked, but in an 8-inch scope with around 80x magnification it appeared as a small, faint and diffuse patch of light, with no hint of resolved stars. While it might not have the glittering grandeur of some of our previous targets, it's nonetheless an interesting object to tick off here.

SEEN IT ☐

▲ M79 is a strongly concentrated globular



▼ Several clear chains of stars can be seen within M47

7 M47

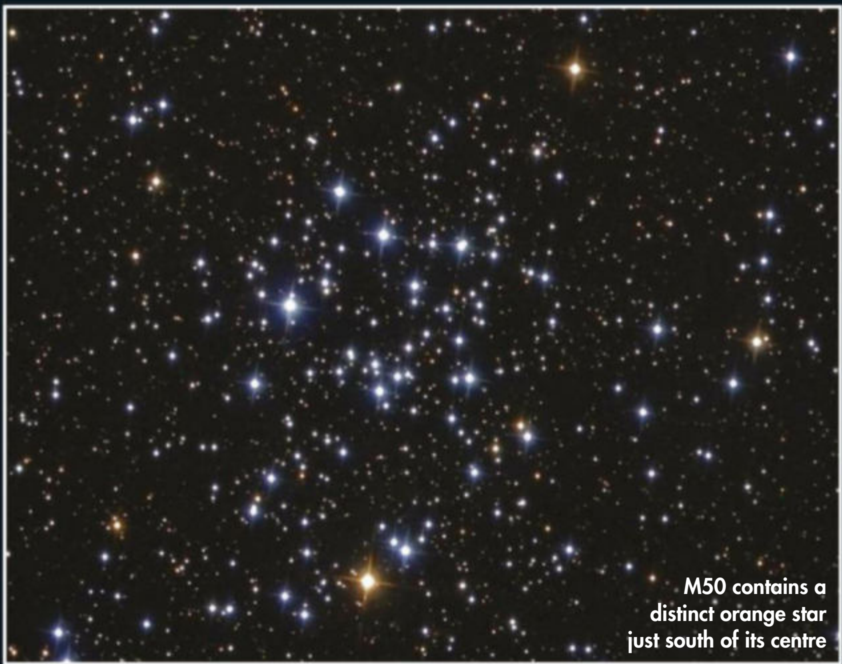
Compared to M79, our next target is a much easier spot. Open cluster M47 can be found in the constellation of Puppis; as you make your way there, you'll head past the dazzling, mag. –1.5 Sirius (Alpha (α) Canis Majoris). Sirius is actually a handy starting point if you're searching for the cluster in binoculars: with a typical pair of 10x50s place Sirius in the lower part of the field and scan east; very soon you'll reach the cluster. It's interesting to compare M47 with its neighbour, M46, which will be in the same field of view with a pair of 10x50s – to our eyes the latter appears fainter and less well resolved in the binoculars. In an 8-inch scope with around 80x magnification, M47 appears as an attractive, loosely-scattered collection of relatively bright stars including several chains. ▸

SEEN IT ☐

8 M50

▸ Our next target, the open cluster M50, lies about 10º away in the neighbouring constellation of Monoceros and, like M47, sits among the star fields of the winter Milky Way. If you observed M47 and M46 with binoculars, you can scan in a northwesterly direction to pick M50 up; alternatively you can go back to brilliant Sirius and from there 'star hop' roughly north-northeast to mag. +4.0 Theta (θ) Canis Majoris before making a final hop to M50 itself; there's a conspicuous diamond of stars next to the cluster that should aid identification in binoculars. In 10x50s, M50 appears rather fuzzy and barely resolved, while in an 8-inch scope, using a magnification of approximately 80x, it appears as a pretty scattering of stars.

SEEN IT ☐



M50 contains a distinct orange star just south of its centre

9 NGC 2244

We're staying in Monoceros now, but moving north and west a little to explore two objects that lie in the swathe of the Milky Way between mag. +0.5 Betelgeuse (Alpha (α) Orionis) and mag. +0.4 Procyon (Alpha (α) Canis Minoris). The first is the open cluster NGC 2244. Astrophotographers will be familiar with this object as it's the star cluster that lies at the centre of the beautiful Rosette Nebula. In 10x50 binoculars the cluster has a very obvious and compact rectangle shape, which is made up of what appears to be – in 10x50s at least – three pairs of stars. To find the cluster in binoculars simply sweep east and a little way south from Betelgeuse. In an 8-inch scope with roughly 50x magnification many more cluster stars become apparent, making this grouping a fine sight in a wide-angle eyepiece.

SEEN IT ☐

▸ NGC 2244 sparkles within the Rosette Nebula

10 Christmas Tree Cluster

The second object we're going to visit in this part of the sky is the beautiful Christmas Tree Cluster, which is catalogued as NGC 2264 if you're using a Go-To telescope mount to follow this sky tour. So close is it to NGC 2244 that the two clusters just about fit in the same field of view with a pair of 10x50 binoculars – all you need to do is scan upwards by 5º in a roughly north easterly direction from NGC 2244. The little upside-down triangular shape of the 'tree' is visible in 10x50s and would be an ideal target for larger binoculars. If you're observing with a telescope, use a low magnification and you'll have no problem making out the tree's shape. The mag. +7.8 star 15 Monocerotis marks the tree's trunk.

SEEN IT ☐

NGC 2264's stars form a festive tree – but remember, it appears upside down

11 NGC 2281

Our penultimate target sits far from Monoceros in the constellation of Auriga. Auriga of course has some particularly beautiful open clusters in it – notably M36, M37 and M38 – but it's NGC 2281 that we're looking for today. In an 8-inch scope at a magnification of roughly 50x, it appears as a pretty collection of a few loosely scattered stars with a little 'diamond' of what look like slightly brighter stars at its heart. In 10x50 binoculars the cluster appears very small but, even from a suburban viewing site, it looks like it is set in a long, rich star field 'island'. To help identify the cluster in binoculars there's a conspicuous line of stars that runs north to south nearby. These include mag. +4.8 50 Aurigae, mag. +5.7 51 Aurigae and mag. +5.3 52 Aurigae.

SEEN IT ☐

▲ A diamond of stars sits central in NGC 2281

M35 is an expansive cluster, spanning an area of sky almost as large as the full Moon

12 M35

With our tour of some of winter's finest star clusters now approaching its end, we're going to finish with an especially beautiful object, the open cluster M35 in the constellation of Gemini. It's easily seen in 10x50 binoculars. Careful observation will show its granular appearance, something that becomes more clearly visible if you use averted vision. To locate M35 in binoculars use mag. +1.9 Alhena (Gamma (γ) Geminorum) as the starting point of a star hop that goes roughly northwest towards mag. +4.16 Nu (ν) Geminorum before curving in the direction of mag. +2.8 Mu (μ) and mag. +6.0 Eta (η) Geminorum, and the cluster itself. In an 8-inch telescope using around 50x magnification, M35 really is mesmerising with myriad stars in view. In particular, look for the striking bow-shaped chain of stars that curves across the cluster's northeast corner.

SEEN IT ☐

Capturing star clusters on camera

Many of the star clusters covered in this article make for beautiful astro imaging subjects. Some of the brighter ones, like M35, are also ideal 'starter' targets if you're just beginning to experiment in imaging with a telescope and motorised mount.

In general, as long as you're creative with the composition, it doesn't matter what the focal length of your telescope is – though some smaller, fainter, clusters ideally need long exposures through a long focal length telescope to show them well. Long focal length imaging requires a tracking mount that follows the sky smoothly and accurately, perhaps aided by an autoguiding system.

But that's not to say only setups with a telescope and a driven mount can snap striking cluster images. The Pleiades, for example, are bright enough and large enough on the sky that a DSLR and kit lens mounted on a static photo tripod can produce pleasing wide-field images of the cluster sitting over a skyline. You'll need to keep the lens aperture wide open and use a relatively high ISO setting, perhaps in the region of 1600-3200, for shots like these.

As in all fields of astrophotography, careful processing is key when it comes to star clusters. As most cluster images are essentially numerous white dots against a dark background, it can be easy to 'clip' the black point of an image in an attempt to improve contrast or perhaps hide a light pollution gradient. The 'clipping' occurs if you move the leftmost slider in the levels tool of image processing software too far to the right; this will result in an image with a harsh contrast and, worse, you may hide faint cluster stars and other subtle details. Similarly, be careful not to 'stretch' (brighten) a cluster image too far – either using the levels or curves tools – as this can blow out brighter stars, overwhelming any colouration they may be showing. Ⓢ

You don't need a huge setup to start imaging; in some cases a DSLR and tripod will do just fine

TRAPPIST-1 THE SEVEN-WORLD WONDER

A year on from the discovery of seven Earth-sized planets orbiting a distant star, **Louisa Preston** considers what the find means for the hunt for habitable worlds

ESO/N. BARTMAN/SPACEENGINE.ORG

Seven planets are known to orbit ultra-cool dwarf TRAPPIST-1, and they're all roughly the same size as Earth

ABOUT THE WRITER

Dr Louisa Preston is a UK Space Agency Aurora Research Fellow, astrobiologist, planetary geologist and author

NASA/JPL-CALTECH/T.PYLE (IPAC), NASA/JPL-CALTECH/R. HURT (SSC)

▲ We'd like to imagine that some of these planets have seas, but for now all we have is speculation

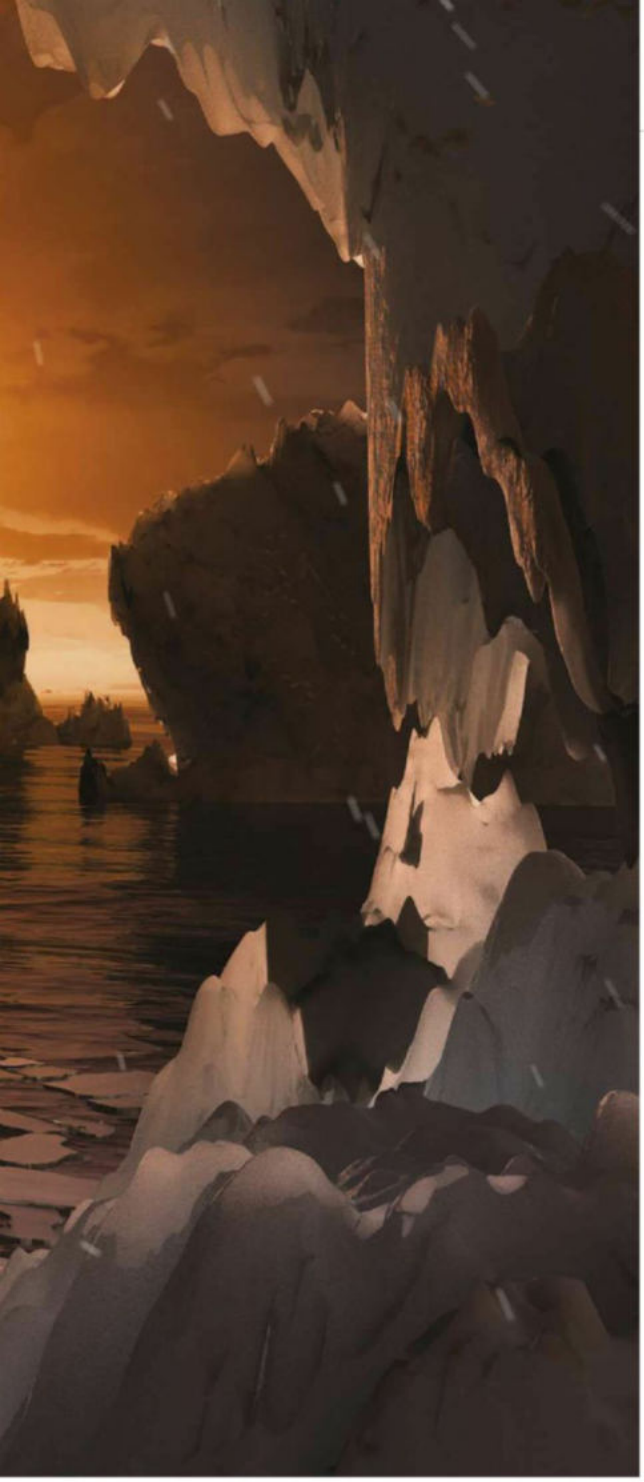
It feels as though the discovery of exoplanets is now a common occurrence. Yet one of these seemingly everyday announcements on 22 February 2017 revealed something quite extraordinary: we appear to be closer than ever to uncovering a second Earth somewhere out there in the cosmos.

That day NASA announced the discovery of the greatest number of Earth-sized exoplanets ever found in the habitable zone of a single small star, called TRAPPIST-1. This ultra-cool dwarf star and system of seven worlds is located a mere 40 lightyears away in the constellation of Aquarius. Three planets were discovered by the star's namesake – TRAPPIST, the Transiting Planets and Planetesimals Small Telescope – in May 2016, with the remaining four found using a panoply of instruments: the Spitzer Space Telescope, the Very Large Telescope, the United Kingdom Infrared Telescope, the Liverpool Telescope and the William Herschel Telescope.

The sizes and masses of the seven planets are all comparable to Earth and Venus, and their bulk densities hint that they are likely to be rocky. While this doesn't mean any of these worlds are an Earth 2.0, that they're inhabited or indeed even habitable – we don't know anything about the conditions on their surfaces yet – this system is going to be one of the best laboratories we have for understanding the evolution of small planets. It brings us ever closer to locating habitable worlds outside our own planetary domain.

Familiar, and yet not

This alien yet familiar multi-planet system looks like a compact version of our own. A family of seven rocky worlds that are closer to TRAPPIST-1 than Mercury sits to the Sun – so tightly packed that a



NO NEW EARTH?

Michaël Gillon's team discovered the TRAPPIST-1 system, but he doesn't think we'll find Earth 2.0 among its array of planets

The planets around the ultra-cool star TRAPPIST-1 are clearly not an Earth 2.0, because they are orbiting a very different kind of star to our own Sun. These seven worlds receive much more radiation and high energy photons, or light, and also they probably are tidally locked, meaning they always point the same side towards their star, just as the Moon does around Earth. Even if the planets are rocky, and even if they do have liquid water on their surfaces, their climates and environments would be completely different from what we're used to. They are certainly not Earth's twins.

There is the possibility of liquid water and maybe life on their surfaces, but these things have yet to be detected. Now we are trying to discover whether their composition is consistent with that of Earth, and we are trying to detect the first traces of an atmosphere. There are theories that say the atmospheres could have been eroded by the star, or maybe they survived. The planets could have liquid water on the surface, or perhaps they're completely barren, like a desert.

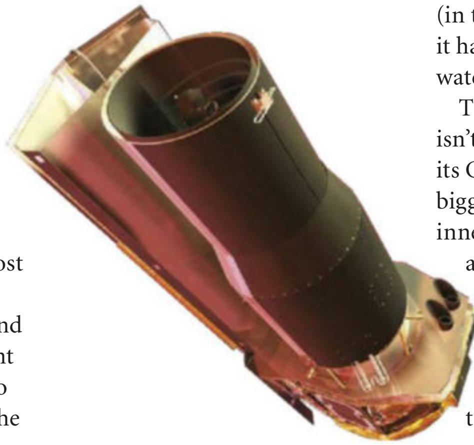
We are able to directly measure the atmospheric properties of the planets, if they have atmospheres. When exoplanets pass in front of a star, a fraction of the starlight is filtered by their atmospheres, so we can measure the effect of this filtration and learn more about what the conditions might be like on the planet. We are still waiting for further observations, but these observations are coming.

When the James Webb Space Telescope is launched in 2019, we hope it will help us explore the atmospheres of the seven planets, if they have any. We can then discover more about their surface conditions and answer other unsolved questions. We are set to learn a lot more about the planets in the coming years and we can be pretty excited, but I don't think we should be expecting signs of alien life any time soon!

"Their climate and environment would be completely different"

year there lasts less than two weeks. These planets are likely to be tidally locked, with one face permanently gazing at the star and the other in perpetual darkness. It's a type of orbit that would create extremes of temperature and very exotic conditions for possible life forms to deal with.

Yet despite this intimacy with their host star, the worlds avoid being scorched as their red dwarf host is roughly a thousand times dimmer than the Sun. The amount of radiation received by a planet is key to evaluating its habitability and three of the worlds, TRAPPIST-1e, f and g, receive similar amounts of radiation to Venus, Earth and Mars. They are within the star's 'Goldilocks Zone', an orbital region where it's not too hot and not too cold so that



▲ Spitzer was one of the telescopes involved in the discovery of the TRAPPIST-1 planets

(in theory) an Earth-like rocky planet, should it have an atmosphere, could support liquid water on its surface.

This newly discovered system's closest analogue isn't in fact our Solar System itself, but Jupiter and its Galilean moons. TRAPPIST-1 is only 1.1 times bigger than Jupiter and the distance between its inner and outermost planets is almost the same as that between Io and Callisto. Its six inner planets also form a nearly resonant chain of orbits, meaning that in the time it takes for the innermost planet to orbit the star eight times, its outer siblings make five, three and two orbits. Dr Elizabeth Tasker, an exoplanet researcher at the Japanese space agency JAXA's Institute for Space and Aeronautical Sciences, explains the relevance of this. "Computer models suggest that resonance occurs when planets migrate inwards towards the star from where ▸

EXPLORING EXOMOONS

As the discovery of exoplanets becomes commonplace, the search turns to the satellites that may be in orbit around them

It is thought that the TRAPPIST-1 planets are unlikely to have large moons, as we would have seen them already in the transit study. Smaller moons up to 300km in radius would be difficult to detect, however. Yet in our Solar System, Jupiter alone has 67 moons and, given we have discovered five times as many gas giants in the temperate zone around other stars compared with terrestrial-sized worlds, exomoons are likely to be out there. So far we haven't found any, but this isn't because we haven't been looking; they are just hard to find.

To detect the presence of an exomoon we look for an additional drop in light as a planet transits across its host star. But these dips will be shallow and easily missed. Indirect methods like looking for a moon's gravitational influence on its host planet are now routinely employed as part of the search.

The closest we have come is through the HEK project (the Hunt for Exomoons with Kepler) led by David Kipping, assistant professor of astronomy at Columbia University in New York. His team are searching for tiny fluctuations in brightness and transit crossings and, during the summer of 2017, spotted a possible Neptune-sized candidate exomoon 4,000 lightyears away, orbiting a planet around a Sun-sized star called Kepler-1625. To confirm or deny the existence of what might be the first discovery of a satellite outside our Solar System, Kipping's team will utilise the power of the Hubble Space Telescope. The results are expected mid-2018, so watch this space.

There are many moons around Jupiter and Saturn – so why not other gas giant exoplanets?

▲ The planets are all closer to their star than Mercury is to ours, and they have short years to match

▸ they originally formed," she says. "If the TRAPPIST-1 worlds formed farther out, they may have formed with way more ice. As the planets moved to warmer climes, this ice could have melted to produce a global ocean." This presents exciting habitability prospects for the TRAPPIST-1 system, as water is intimately connected with life on Earth.

At the time of its discovery, TRAPPIST-1 and its system of planets was believed to be at least 500 million years old, but since then the star has been shown to be much older: between 5.4 and 9.8 billion years, or up to twice as old as our own Solar System. It is unclear what this older age means for the habitability of these worlds.

NASA/JPL-CALTECH/R. HURT (IPAC), NASA/JPL-CALTECH/T.PYLE (IPAC), NASA GODDARD SPACE FLIGHT CENTRE, NASA/DESIREE STOVER, ESA–C. CARREAU

THE TRAPPIST-1 SYSTEM

The key characteristics of the seven worlds: we might not be able to tell if any have liquid water on their surfaces, but we have been able to work out their orbits and sizes

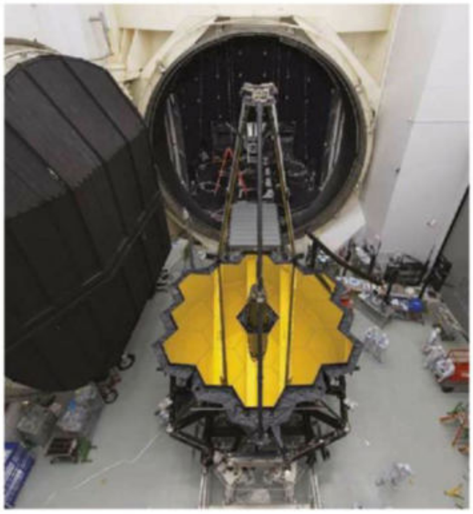
b	c	d	e	f	g	h
Orbital period: 1.51 days	Orbital period: 2.42 days	Orbital period: 4.05 days	Orbital period: 6.10 days	Orbital period: 9.21 days	Orbital period: 12.35 days	Orbital period: 20 days
Distance to star: 0.011 AU	Distance to star: 0.015 AU	Distance to star: 0.021 AU	Distance to star: 0.028 AU	Distance to star: 0.037 AU	Distance to star: 0.045 AU	Distance to star: 0.06 AU
Radius relative to Earth: 1.09	Radius relative to Earth: 1.06	Radius relative to Earth: 0.77	Radius relative to Earth: 0.92	Radius relative to Earth: 1.04	Radius relative to Earth: 1.13	Radius relative to Earth: 0.76

1 AU = the average Earth-Sun distance, about 150 million km

THE HUNT MUST GO ON

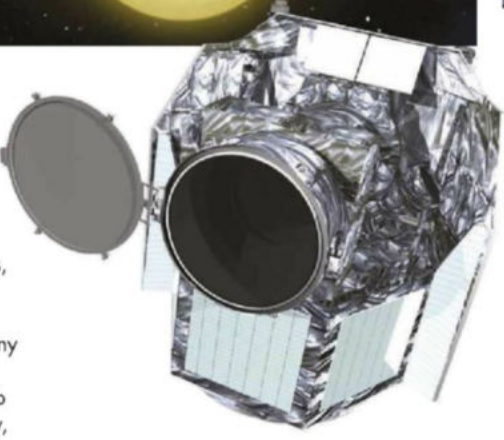
Future telescopes will enable astronomers to step up the search for planets beyond our Solar System

The Transiting Exoplanet Survey Satellite (TESS): launches March 2018



▲ The James Webb Space Telescope: launches 2019

While we currently can't say anything about the surface conditions on the TRAPPIST-1 worlds, our next generation of instruments have the potential to change all that. The Transiting Exoplanet Survey Satellite (TESS) is due to launch in 2018 on a two-year mission to monitor the brightness of more than 200,000 stars, searching for dips as exoplanets transit. The stars TESS will study are all within 200 lightyears of the Sun, which means any exoplanets discovered will be suitable for further study using the NASA James Webb Space Telescope (JWST). This observatory, due for launch in 2019, will survey the properties of exoplanetary atmospheres orbiting nearby cool M-dwarf stars. If the innermost TRAPPIST-1 planets had the same levels of ozone as Earth does today, it would be detectable by JWST. The Characterising Exoplanets Satellite (CHEOPS) is a European space telescope planned to be launched at the end of 2018, and will measure the radii of known transiting super-Earth to Neptune-mass exoplanets. Longer term, the ESA space observatory PLATO (Planetary Transits and Oscillations of Stars), due for launch in 2026, will search for exoplanet transits of up to one million stars, focusing on finding an Earth 2.0.



▲ CHEOPS: launches late 2018

Older stars flare less than younger stars, so the orbiting worlds are safer. However, since the planets are so close to the star they have already soaked up billions of years of high-energy radiation, which could have boiled off atmospheres and large amounts of water. This is useful context for future observations of TRAPPIST-1 and other exoplanets, offering an insight into how planetary atmospheres may form and evolve, and how long they can persist.

"If we can get a glimpse of what is in the air of the exoplanets, we'll get the first hint of what is going on at the surface," says Tasker. And the TRAPPIST-1 siblings may be the best targets yet for this kind of study. This is because they all orbit on the same plane, and this orbital plane passes through the line of sight between us and the star TRAPPIST-1.

Atmospheric secrets

Our view of the system means that we will be able to observe all the planets transiting across the star. During transit, some of the starlight goes through the planets' atmospheres, getting altered by the chemical composition of the air and also by its vertical structure.

As our technology develops in areas like spectroscopy, the convenient alignment of TRAPPIST-1's planets gives us the chance to characterise all seven of the planets' atmospheres – an essential step in understanding their climates and whether they are suitable for habitability.

Already, the instruments and knowledge to do this are in existence. The Hubble Space Telescope can detect hydrogen gas as it escapes from exoplanetary atmospheres, caused by ultraviolet starlight breaking apart water vapour. In August last year, an international team of astronomers used Hubble to study the amount of ultraviolet radiation being received by the TRAPPIST-1 planets. They suggested that the outer planets might still harbour substantial amounts of water, including the three bodies in the habitable zone.

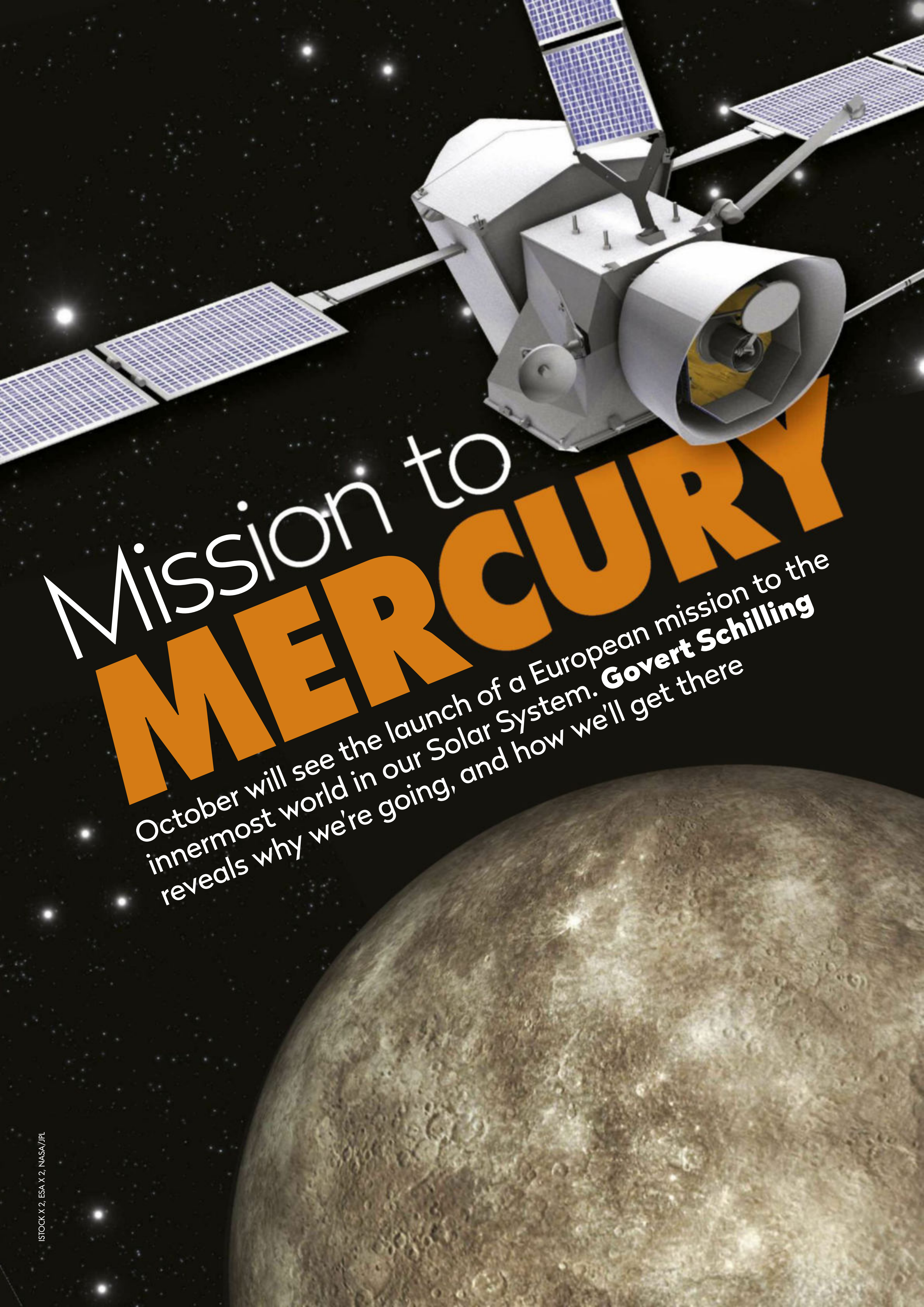
It's a finding that fuels the desire and need to study these worlds further, and using our next generation of ground-based and orbital telescopes, more revelations will be just around the corner.

YOUR BONUS CONTENT

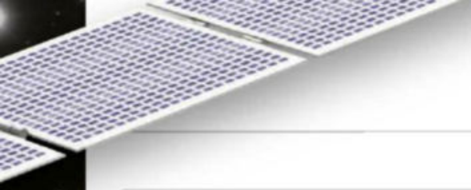
Watch our interview with astronomer Michaël Gillon, who led the team that discovered the TRAPPIST-1 system

Mission to MERCURY

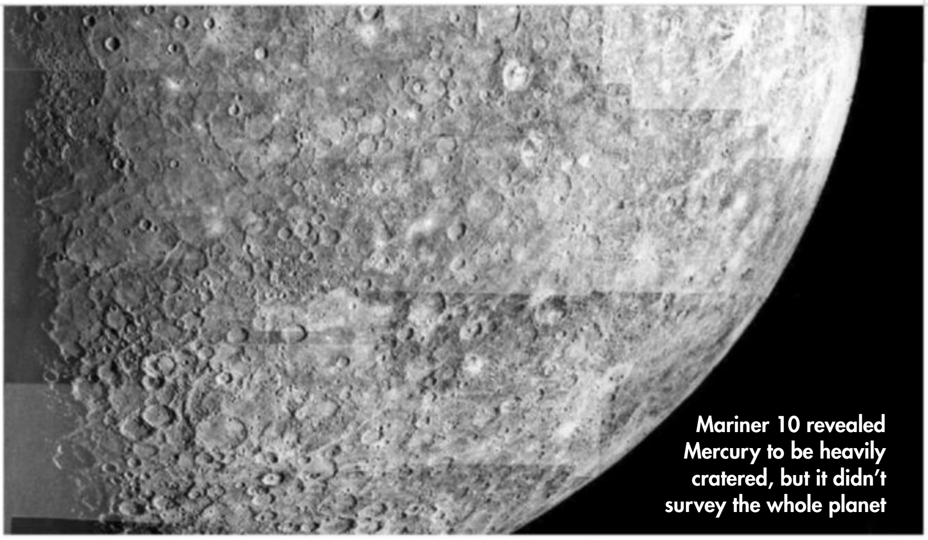
October will see the launch of a European mission to the innermost world in our Solar System. **Govert Schilling** reveals why we're going, and how we'll get there



ISTOCK X 2, ESA X 2, NASA/JPL



ABOUT THE WRITER
Govert Schilling is a space writer, and author of *Ripples in Spacetime*, the story behind the detection of gravitational waves



Mariner 10 revealed Mercury to be heavily cratered, but it didn't survey the whole planet

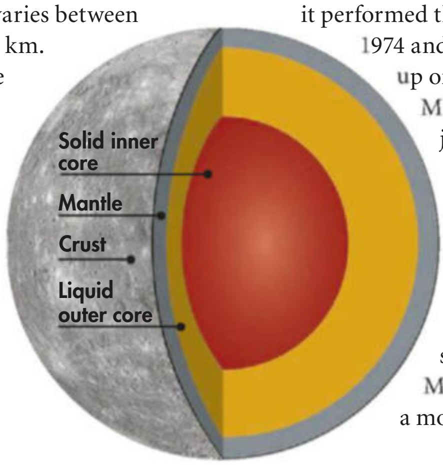
"A peculiar planet of mysteries and surprises" – this is how European planetary scientist Johannes Benkhoff describes Mercury. In October this year, ESA will launch the BepiColombo spacecraft to the Solar System's smallest and innermost planet. Some eight years from now, it will begin studying Mercury in meticulous detail across the electromagnetic spectrum. According to Benkhoff, the mission's project scientist, planetary researchers expect BepiColombo to solve many Mercurial mysteries. It's a planet, he says, that is also a key element in understanding the formation of the Solar System.

The mission's Ariane 5 rocket launch from French Guiana will send two orbiters to the planet: the relatively small Japanese Mercury Magnetospheric Orbiter (MMO) and ESA's 4,100kg Mercury Planetary Orbiter (MPO). Both are mounted on a six-metre tall transfer module that will deliver the two craft into orbit around the 4,879km-diameter planet.

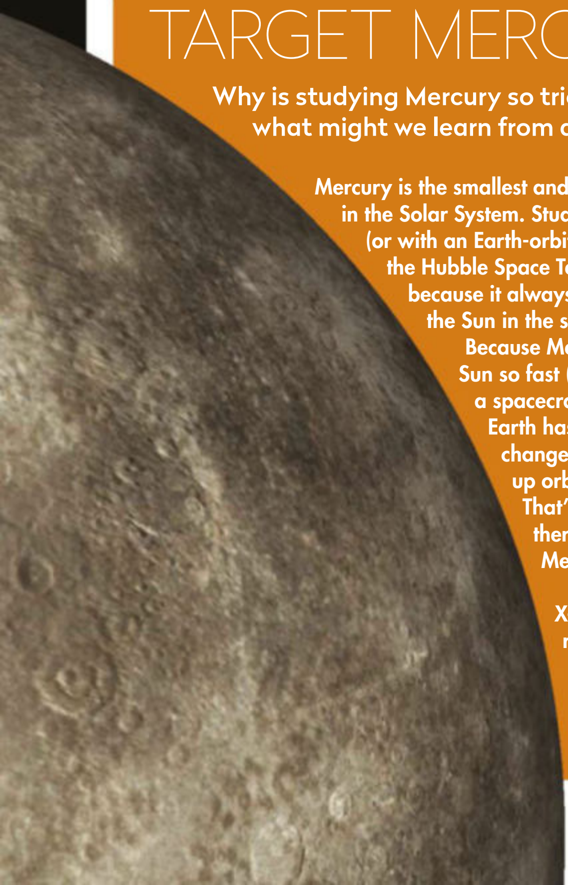
"It's a very harsh environment," says Benkhoff, referring to Mercury's distance from the Sun, which varies between just 46 and 69 million km. "But if we're lucky, the nominal mission duration of one year may be extended up to four years."

Although Mercury is much closer to Earth than, say, Saturn, it's tough to get there, basically because the planet's orbital speed is much higher than Earth's. The first Mercury probe, NASA's Mariner 10, didn't even make it into orbit. Launched in 1973, it performed three close flybys in 1974 and 1975, before ending up orbiting the Sun. Mariner 10 mapped just shy of half of the planet's surface, revealing a crater-pocked landscape. It also discovered a weak magnetic field: quite a surprise, since no one expects Mercury to have retained a molten core.

It would be 30 years before another ▸



▲ **Mercury has a notably different interior to Earth, being mostly core and little mantle**



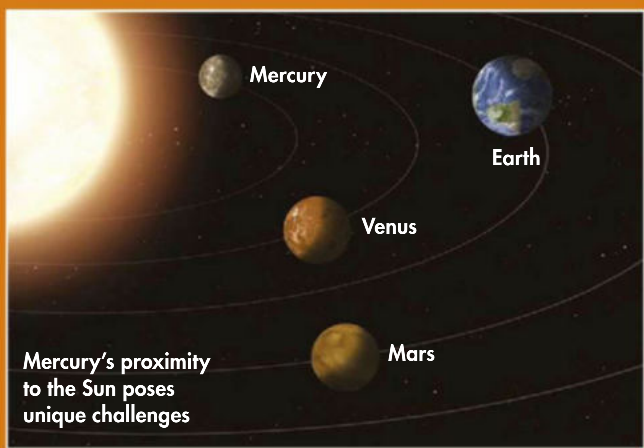
TARGET MERCURY

Why is studying Mercury so tricky, and what might we learn from doing so?

Mercury is the smallest and innermost planet in the Solar System. Studying it from Earth (or with an Earth-orbiting instrument like the Hubble Space Telescope) is difficult, because it always appears close to the Sun in the sky.

Because Mercury is orbiting the Sun so fast (48kms on average), a spacecraft launched from Earth has to undergo a large change in velocity to end up orbiting the planet. That's one reason why there have been so few Mercury probes so far.

Visible light, X-rays and ultraviolet radiation from the Sun are about 10 times more powerful at Mercury than they are on Earth. The solar wind (charged particles from the Sun) is also more energetic. This is another reason why Mercury has remained relatively unexplored.



Mercury's proximity to the Sun poses unique challenges

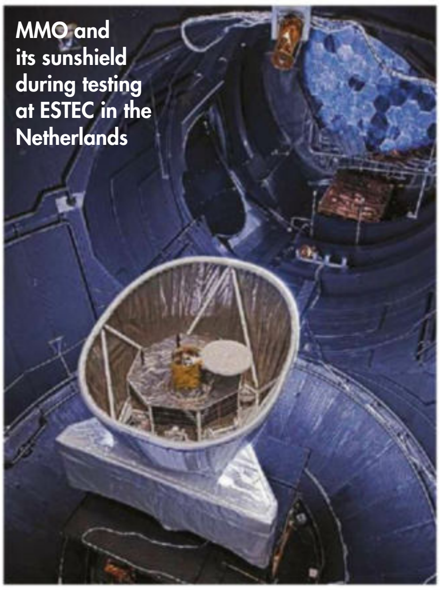
Compared to the other terrestrial planets, Mercury has a very large iron-nickel core. No one knows why. Maybe a huge primordial impact blew away most of its rocky mantle. Or maybe scientists need to adapt their pet theories on the formation of the Solar System.

Learning more about Mercury and its extreme environment will also help in understanding habitable-zone exoplanets that orbit at comparable distances to their parent dwarf stars.

▲ **The entire BepiColombo stack; the sunshield (top) will be jettisoned on arrival at Mercury**

▸ probe set course for Mercury. NASA's MESSENGER spacecraft launched in August 2004, and orbited the barren world between March 2011 and its intentional crash in April 2015. From its polar orbit, MESSENGER collected nearly 290,000 images and mapped the planet's topography. Among other things, it discovered deposits of ice at the floors of permanently shadowed polar craters, mysterious 'hollows' beneath the surface, signs of relatively recent volcanic activity, and a mysterious displacement of the magnetic field by 400km northwards with respect to the planet's centre.

So what's left for BepiColombo to discover? A lot, says former project manager Jan van Casteren at the European Space



MMO and its sunshield during testing at ESTEC in the Netherlands

Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands. Originally, he says, BepiColombo was scheduled to arrive first, but the project was delayed by technological problems, cost overruns and redesigns. "Still, in 2009, ESA's Science Programme Committee decided to give the go-ahead for the mission because of its great scientific potential. BepiColombo is a much more versatile mission than MESSENGER, which was relatively simple."

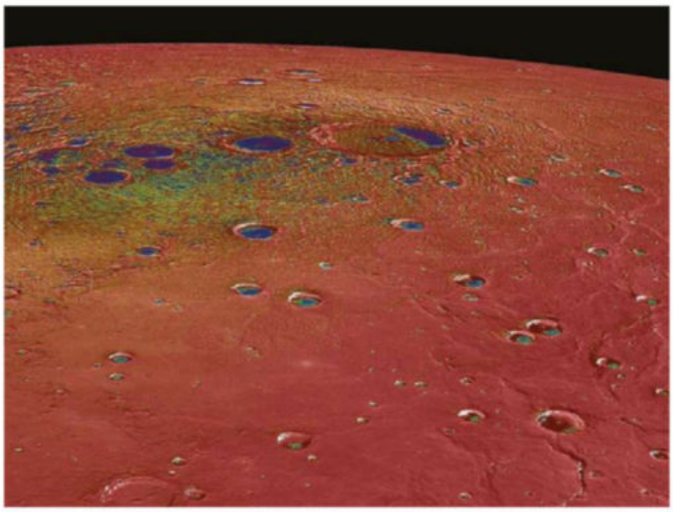
No easy journey

During its seven-year cruise phase, BepiColombo's solar orbit will gradually be tweaked by one Earth flyby, two Venus flybys and no less than six Mercury flybys. This 'gravity assist' technique, pioneered by Mariner 10, was invented by Italian astronomer Giuseppi 'Bepi' Colombo, after whom the mission is named. The craft's versatile ion engine will perform additional orbital corrections. Eventually, in early December 2025, BepiColombo will arrive in its elliptical polar orbit. A few months later, the lowest point of the orbit is brought down to just 250km, and science operations will begin.

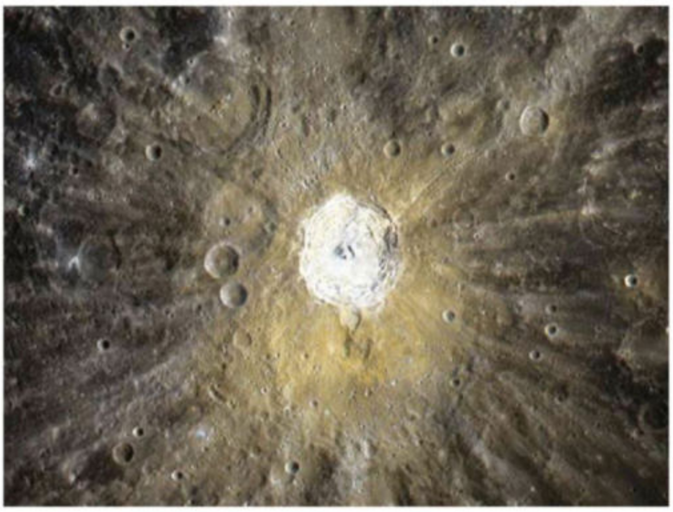
At Mercury, a spacecraft receives about 10 times more solar energy than it would in Earth orbit: some 14,500 watts per square metre. Moreover, Mercury's surface is so hot (430°C) that BepiColombo's main orbiter needs to be protected from the planet's infrared radiation, which delivers more energy: 5,500 watts per square metre. To cope with these extremes, the craft is completely wrapped in thick, multilayer thermal blankets. A huge contraption of silver-coated titanium fins always points away from the planet to radiate excess heat away into space.

You might expect that the use of solar panels is straightforward when you're so close to the Sun, but you'd be wrong, as Markus Schelkle of Airbus Defence and Space in Germany (the spacecraft's prime contractor) explains. "The solar array had to be newly developed using novel materials," he says. "It's very difficult to make them resistant to both high temperatures and strong ultraviolet radiation." The same is true for the large solar arrays on BepiColombo's transfer module, which provide the energy for the ion engine. "Developing the solar arrays took as long as developing the whole spacecraft," says Schelkle.

As the MPO studies the planet up close, the smaller MMO will monitor the



▲ **Mercury's north polar region, coloured by maximum surface temperature – red represents a toasty 125°C or more**



▲ **Kuiper, one of Mercury's younger craters, has unusually red ejecta – perhaps dredged up by the impact that caused the crater**

NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/CARNEGIE INSTITUTION OF WASHINGTON X 3, ESA/C. CARREAU, ESA/JAXA/ANNEKE LE FLOC'H, ESA/ATG MEDIALAB

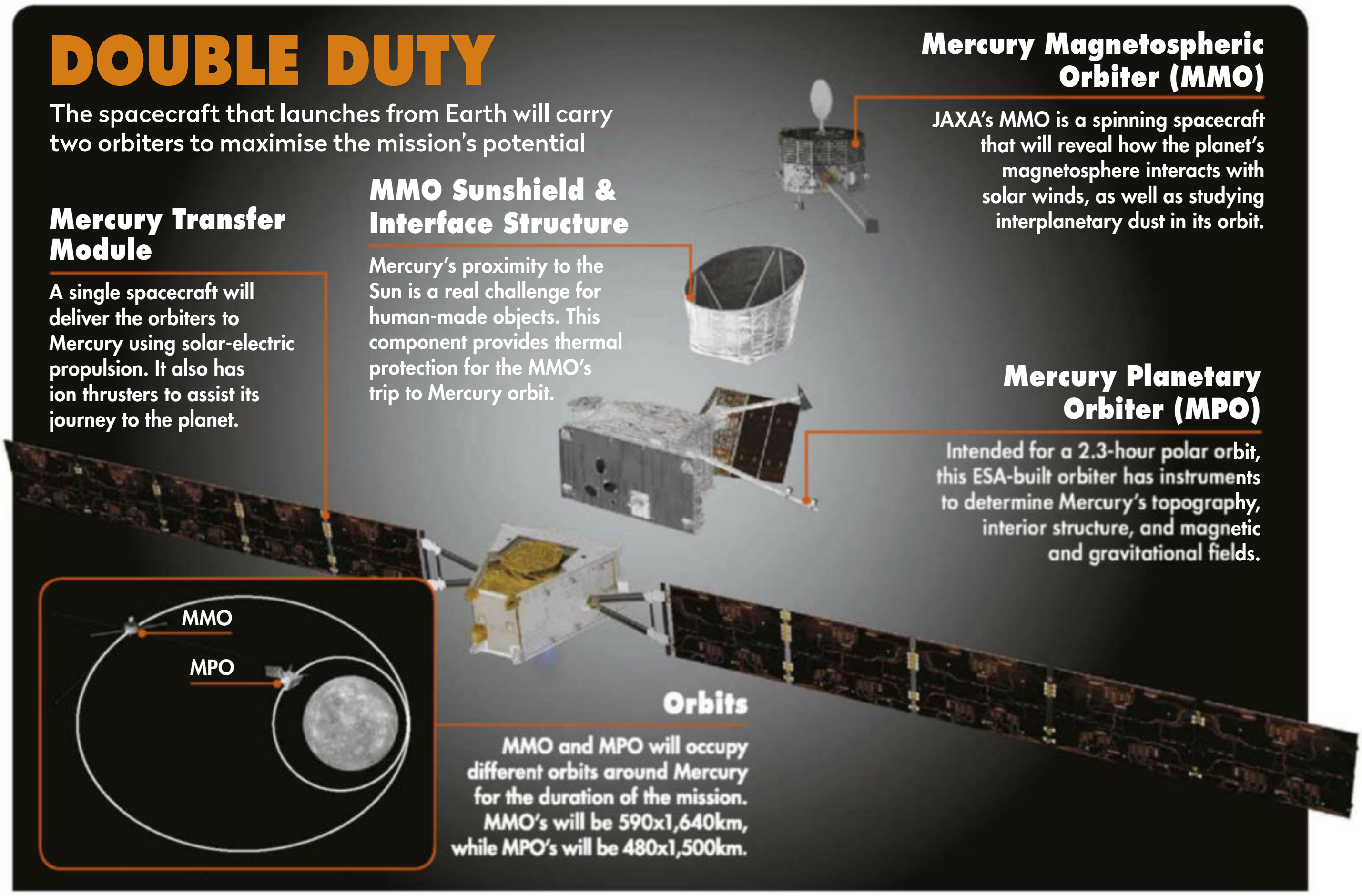
▲ The 'hollows' are a uniquely Mercurial mystery – landforms like these have not been found anywhere else in the Solar System

"You might expect using solar panels to be straightforward when you're so close to the Sun, but you'd be wrong"

solar wind, the planet's magnetic field and the extremely tenuous sodium-rich 'exosphere'. Because of strong solar wind buffeting, Mercury's magnetosphere can sometimes be pushed back all the way to the surface. As a result, the solar wind directly interacts with the surface, possibly releasing sodium atoms in the process. "It's one of the questions we want to answer," says Hajime Hayakawa of the Japanese space agency JAXA. Another big issue he hopes MMO will solve is the mysterious 'shift' of Mercury's magnetic dipole.

Meanwhile, as project scientist Benkhoff recounts, the MPO will map the elemental and chemical composition of the planet's surface, look for morphological changes in the mysterious subsurface 'hollows' (which may be due to the loss of volatiles), hopefully elucidate the origin of the polar ice deposits and study the planet's relatively large iron-nickel core. "Also," says Benkhoff, "Mercury's potassium/thorium ratio is much higher than current planetary formation models predict. The mission may shed new light on the origin of the Solar System."

Van Casteren is confident that the ambitious €1.65 billion mission will be worth every penny. "The highest-resolution images will reveal details as small as 5m," he says, "and BepiColombo has an impressive suite of 11 science experiments. It would have been nice to be the first, but in the long run, it's the science that counts." Ⓢ



PLUS

Stephen Tonkin's
BINOCULAR TOUR
Turn to page 60 for six of this month's best binocular sights

THE SKY GUIDE
February

Brilliant Venus returns to the evening sky this month, visible low in the west-southwest shortly after sunset.

PETE LAWRENCE

DON'T MISS...

- ▷ Venus points the way to a very thin Moon
- ▷ Ganymede's dark shadow crosses Jupiter's globe
- ▷ Mars meets its rival on equal terms

Written by
PETE LAWRENCE
Pete Lawrence is an expert astronomer and astrophotographer, and a presenter of *The Sky at Night* on BBC Four.

FEBRUARY **HIGHLIGHTS**

Your guide to the night sky this month

THURSDAY 1 ▶

Mag. +1.4 Regulus (Alpha (α) Leonis) appears 50 arcminutes from the 97%-lit waning gibbous Moon as it rises. Look for the pair low in the east just after 19:00 UT.

THURSDAY 8

This morning's 45%-lit waning crescent Moon occults mag. +3.9 Gamma (γ) Librae just after 03:12 UT as seen from the centre of the UK. Jupiter can be seen 4.75° southwest of the Moon at this time.

FRIDAY 9

This morning's 35%-lit Moon forms an approximate line with mag. +1.1 Mars and +1.0 Antares (Alpha (α) Scorpii) as all three objects rise. Look out for the trio from around 04:30 UT.

SUNDAY 11

Early risers may catch a glimpse of Saturn 4° to the southeast of an 18%-lit waning crescent Moon this morning. Catch them just before 06:00 UT when they will appear low above the southeast horizon.

MONDAY 12 ▶

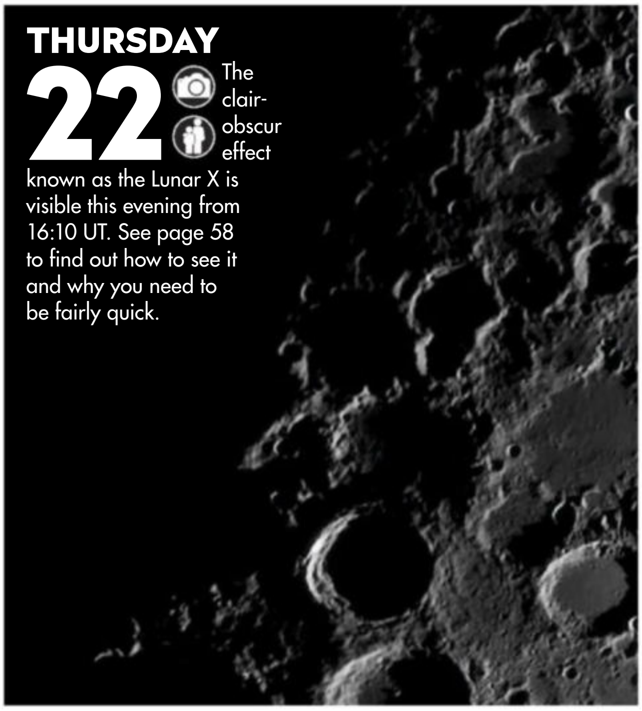
Catch Mars 5° to the north of Antares (Alpha (α) Scorpii) this morning. The name Antares literally means 'rival of Mars', a reference to how similar the star looks to the planet. Tonight is a great opportunity to do a direct comparison. See page 53.

THURSDAY 15

The Moon is new today, making this a great time to look out for our Deep-Sky Tour targets. This month we're looking at bright galaxies in Leo.

FRIDAY 16 ▶

This evening presents an excellent opportunity to spot a thin Moon thanks to the presence of emerging twilight planet Venus. See page 52.



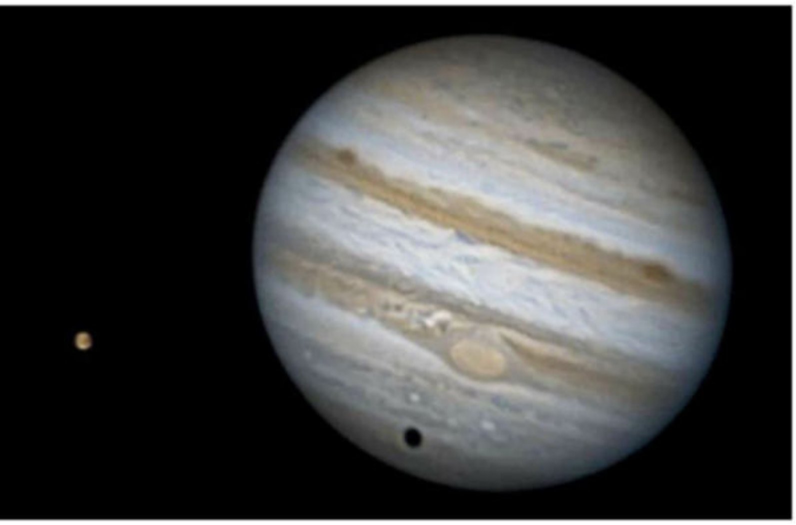
THURSDAY 22

The clair-obscur effect known as the Lunar X is visible this evening from 16:10 UT. See page 58 to find out how to see it and why you need to be fairly quick.

FAMILY STARGAZING – 22 FEB

The appearance of the Lunar X on 22 February is perfect for young observers as it forms early in the afternoon. As it best suits low to medium magnifications it is also ideal for small telescopes. The X starts to form around 16:10 UT and should be fairly easy for young eyes to see from around 16:30 UT. As the early evening sky darkens, the X should become more pronounced, appearing fully formed between 18:30-19:30 UT. By 20:40 UT it will have gone. See page 58 to find out what it is and exactly where to look.
www.bbc.co.uk/cbeebies/shows/stargazing

PETE LAWRENCE X 9



◀ SATURDAY 10

There is a good opportunity to watch a transit of Jupiter's largest moon Ganymede as it passes across Jupiter's north polar region this morning. Start watching from 02:20 UT when Ganymede can be seen approaching Jupiter's northeast limb. See page 53.

TUESDAY 13

Our Star of the Month is mag. +1.9 Castor (Alpha (α) Geminorum) which reaches its highest point in the sky, due south, around 22:00 UT. Take a look at it through a telescope and you may get more than you bargained for.

WEDNESDAY ▶ 14

The faint constellation of Cancer is due south at 23:30 UT, and this is a great time to grab a view of the spectacular Messier clusters M44 and M67.

SATURDAY 17

A view of Jupiter through a scope this morning will reveal Ganymede's large shadow passing across the planet's disc. The shadow transit starts at 01:28 UT and lasts for two hours.

◀ TUESDAY 20

Mag. –1.5 Sirius (Alpha (α) Canis Majoris), the brightest night-time star, is located due south at 19:00 UT. This is a great time to try and spot its tricky companion, the mag. +8.5 white dwarf star known as the Pup.

FRIDAY 23

It may be possible to see mag. +0.9 Aldebaran (Alpha (α) Tauri) occulted by the Moon in daylight. The star disappears behind the dark limb at 16:33 UT, emerging from the bright edge at 17:42 UT. Start observing 10 minutes beforehand so you don't miss anything.

SATURDAY 24

This morning offers another chance to catch the impressive sight of Ganymede's shadow transiting Jupiter's disc. See page 53.

SUNDAY 25

Our Comets and Asteroids target for February is asteroid 51 Nemausa, which reaches opposition today. This tiny world will appear as a 10th-magnitude dot in the faint constellation of Sextans.

WEDNESDAY ▶ 28

Venus is slowly creeping back into view in the evening twilight. This evening it sets one hour after the Sun. Wait until after sunset and try and spot mag. –1.3 Mercury 2.5° to the west of Venus, in the direction of the Sun.

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY
Objects marked with this icon are perfect for showing to children

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

BINOCULARS
10x50 recommended

SMALL/ MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

Assisted thin Moon HUNTING

WHEN: 15 minutes after sunset on 16 February

Thin lunar crescents can be hard to spot in twilight skies – unless you have a guide, like Venus

The lunar cycle arbitrarily begins at new Moon. The Moon's cycle age resets to zero at this phase, after which its phases wax and wane until the next new Moon occurs, at which time it resets to zero again. It's commonplace to describe, for example, the Moon 24 hours after new to have an age of one day. Although slightly misleading, as the Moon's actual age is closer to 4.51 billion years, this scheme does help make sense of the lunar cycle.

Spotting the Moon two or more days after new Moon isn't really that hard. At such times, the Moon's apparent separation from the Sun will have increased sufficiently to place it in a darker part of the evening twilight after sunset. Also, at this time of year, the earlier phases in the Moon's cycle are best placed in the west after sunset, making that thin lunar crescent much easier to see.

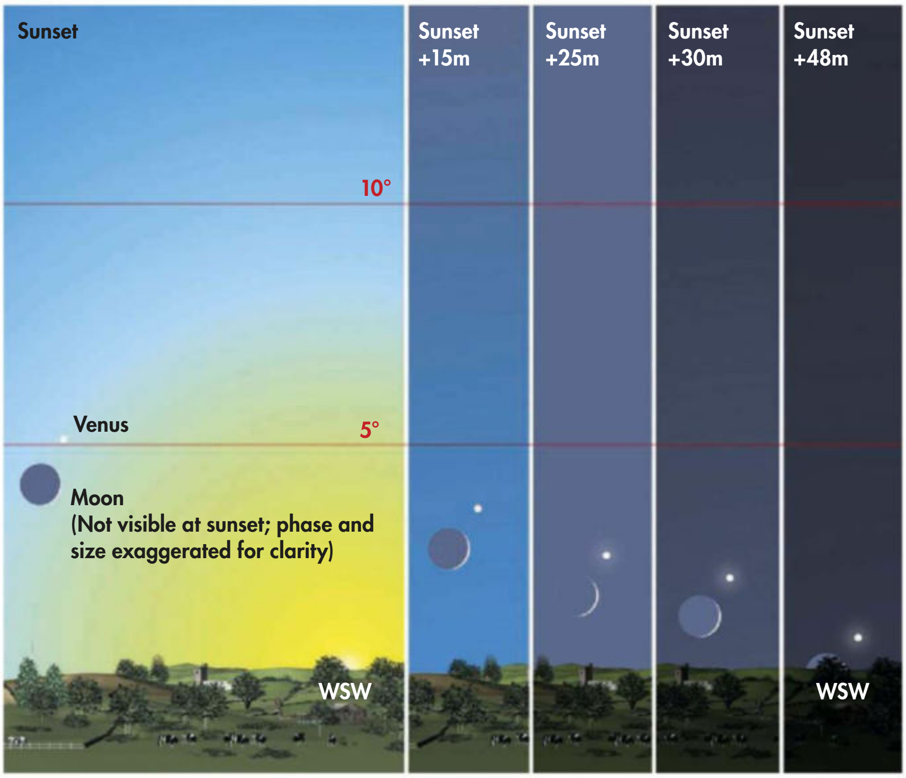
Between new and two-day-old Moons, the Moon's thin crescent is much harder to see. It is possible to detect the Moon when it's in its new phase when it is optimally positioned above or below the Sun in the sky, but this requires expertise, great care and a specialist camera setup.

The theoretical threshold for waxing crescent Moon visibility is known as the Danjon Limit, stating that a Sun-Moon separation of at least 7° is required. Following sunset on 16 February it may be possible to see a very thin lunar crescent with the assistance of a telescope, binoculars, or, given really transparent conditions, with the naked eye. On this date, the Moon appears separated by 9° and 14 arcminutes from the Sun.

If you've ever tried to spot a very thin lunar crescent before you'll know just how hard this can be. On the evening of 16 February you'll be looking for the most delicate arc of white moonlight struggling for visibility against a bright evening twilight sky.

Fortunately there is help at hand in the form of brilliant Venus. This amazing planet is so bright that it can be seen in daylight so long as you know where to look, so finding it in the evening twilight shouldn't be a problem. Once Venus has been located, look for the Moon 1.1° south of Venus. At this time of evening from the UK this places the Moon below-left of the planet and for reference, 1° is the width of your little finger at arm's length.

If you manage to see this amazingly thin Moon you'll be looking at a very young lunar crescent, one that is just 20.3 hours old and 0.7% illuminated.



PETE LAWRENCE X 4

▲ Relative positions and altitudes of the Moon and Venus following sunset on 16 February

Jupiter moon events

WHEN: Dates and times as stated below

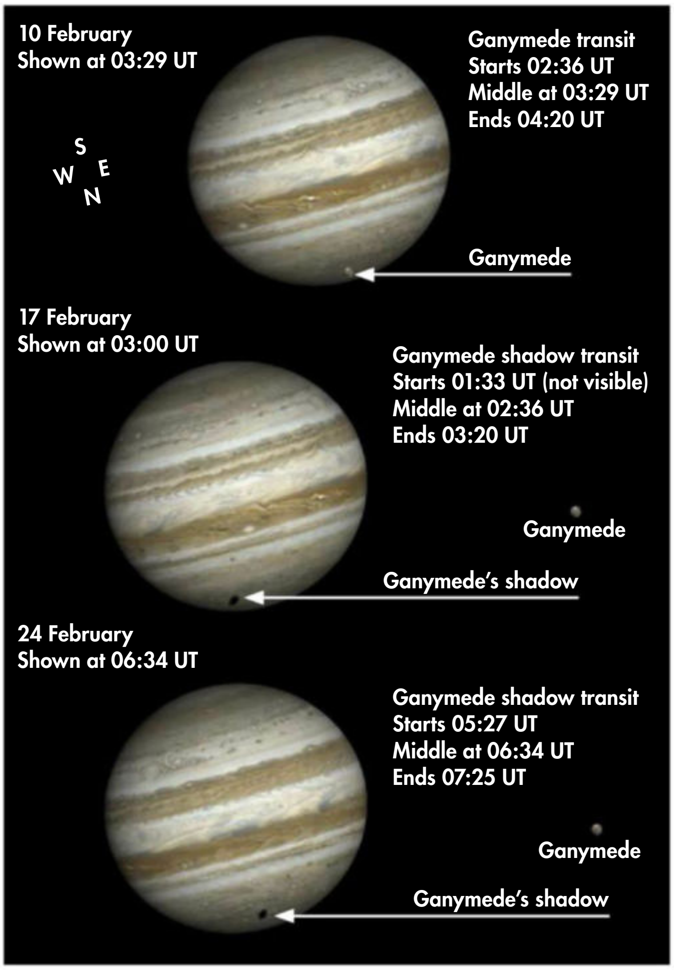
There are a number of interesting events involving Jupiter and Galilean moon Ganymede this month. On 10 February, Ganymede appears to cross Jupiter's disc in an event known as a transit. The crossing starts at 02:36 UT just after Jupiter rises, and ends at 04:20 UT. Ganymede is on Jupiter's central meridian at 03:29 UT. Watching Ganymede approach the northeast limb is fascinating and it's an interesting exercise to see whether you can detect both the colour and a tangible disc size for the moon. Ganymede will have an apparent diameter of 1.4 arcseconds during the transit.

On 17 February, it's the turn of Ganymede's giant shadow to steal the show. This is a really impressive sight when it crosses Jupiter and is worth getting up early for. Sadly, the transit starts at 01:33 UT, when Jupiter is below the horizon, but it should be possible to see the final stages as the event draws to a close at 03:20 UT. During the shadow transit Ganymede can be seen northeast of Jupiter, itself due to transit between 06:46 UT and 08:06 UT, the latter stages taking place after sunrise.

A second and more favourably placed Ganymede shadow transit occurs on 24 February. This transit starts at 05:27 UT with the shadow on the centre line of the planet at 06:34 UT. This event concludes at 07:25 UT, just a few minutes after sunrise. It'll be interesting to stick with Jupiter as the dawn twilight begins to brighten to see whether you can see the shadow transit through.

It is possible to see Jupiter through a scope in daylight, but visually contrast tends to be quite poor. If you intend to image the transit, a mono camera fitted with an infrared pass filter will help darken the blue, daylight sky and improve visibility of Jupiter's disc.

▼ Ganymede and its shadow transit Jupiter several times this month



Mars meets its rival

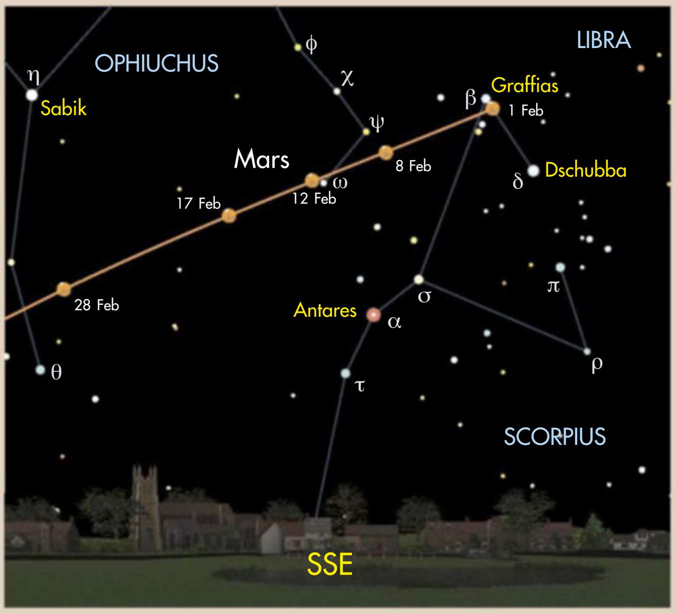
WHEN: From 05:30 UT, 8-17 February

The name Antares (Alpha (α) Scorpii) is from the ancient Greek meaning 'equal to' or 'rival of' Mars. Although Antares appears at its best in the summer months, February sees the star's rivalry with the Red Planet come to a peak, Mars passing just to the north of Antares.

Normally Mars easily wins any comparison contest because it generally shines much brighter than Antares. However, at present the planet is moving along a remote part of its orbit relative to Earth and consequently appears dim. By coincidence, the visual brightness of both Antares and Mars will be virtually identical (mag. +1.0 and mag. +1.1) during this month's close visual encounter in the morning sky, and this is an ideal time to see whether they really do look similar.

The rivalry occurs because Antares is a red supergiant star and to the naked eye its redness generates the same orange hue as Mars. Despite this close apparent pass, which sees Mars come to within 5° of Antares, in reality the star is located 22.2 million times farther away than the planet; 550 lightyears versus 1.57 AU.

The best time to see the meeting will be around 05:30 UT between 8-17 February low in the south-southeast. The closest separation occurs on the morning of 12 February.



▲ Mars and Antares will be low in the south-southeast, both of almost identical brightness during their close encounter mid month

THE NORTHERN HEMISPHERE IN FEBRUARY

KEY TO STAR CHARTS

Arcturus	STAR NAME
PERSEUS	CONSTELLATION NAME
	GALAXY
	OPEN CLUSTER
	GLOBULAR CLUSTER
	PLANETARY NEBULA
	DIFFUSE NEBULOSITY
	DOUBLE STAR
	VARIABLE STAR
	THE MOON, SHOWING PHASE
	COMET TRACK
	ASTEROID TRACK
	STAR-HOPPING PATH
	METEOR RADIANT
Circlet	ASTERISM
	PLANET
	QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

N, E, S, W, 5° — COMPASS AND FIELD OF VIEW

MILKY WAY

CHART: PETE LAWRENCE

WHEN TO USE THIS CHART

1 FEB AT 00:00 UT
15 FEB AT 23:00 UT
28 FEB AT 22:00 UT

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN FEBRUARY*

DATE	SUNRISE	SUNSET
1 Feb 2018	07:55 UT	16:53 UT
11 Feb 2018	07:37 UT	17:13 UT
21 Feb 2018	07:16 UT	17:32 UT
1 Mar 2018	06:58 UT	17:47 UT

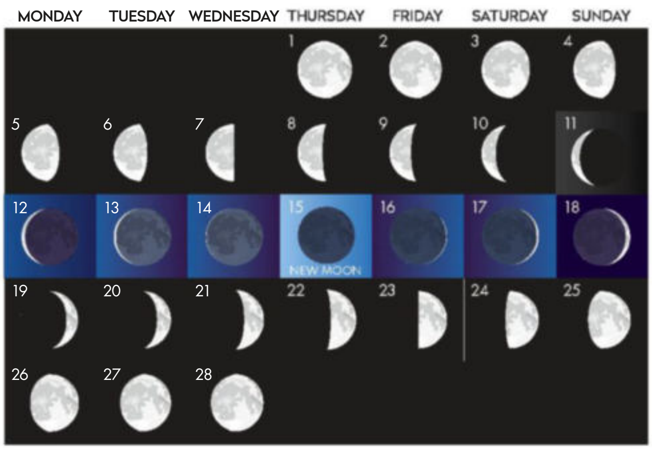
MOONRISE IN FEBRUARY*

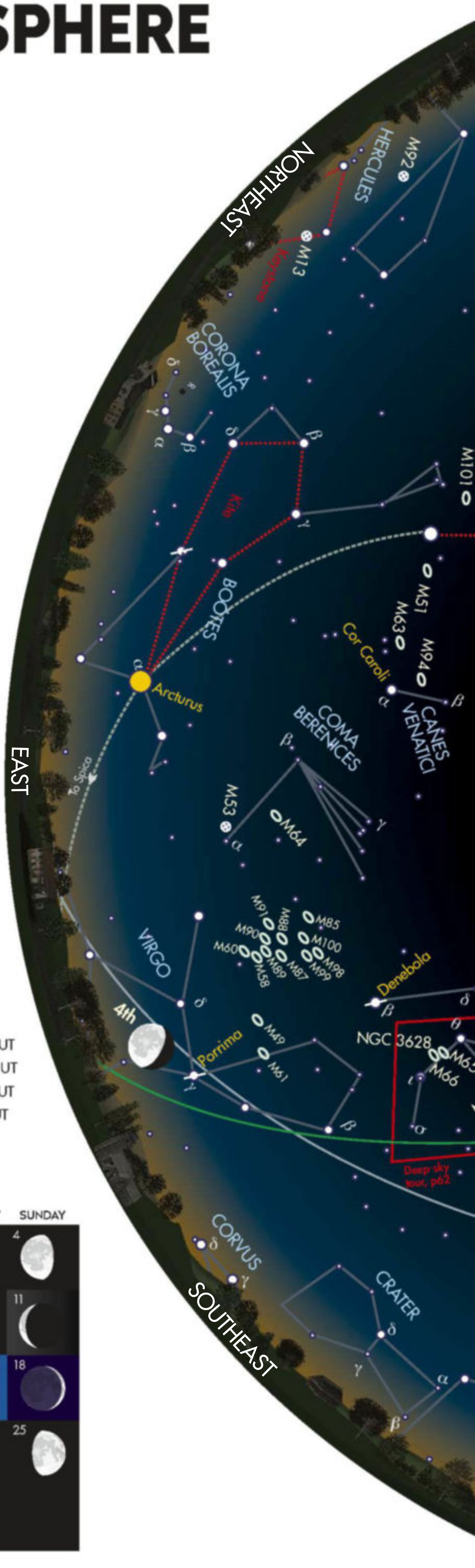
MOONRISE TIMES

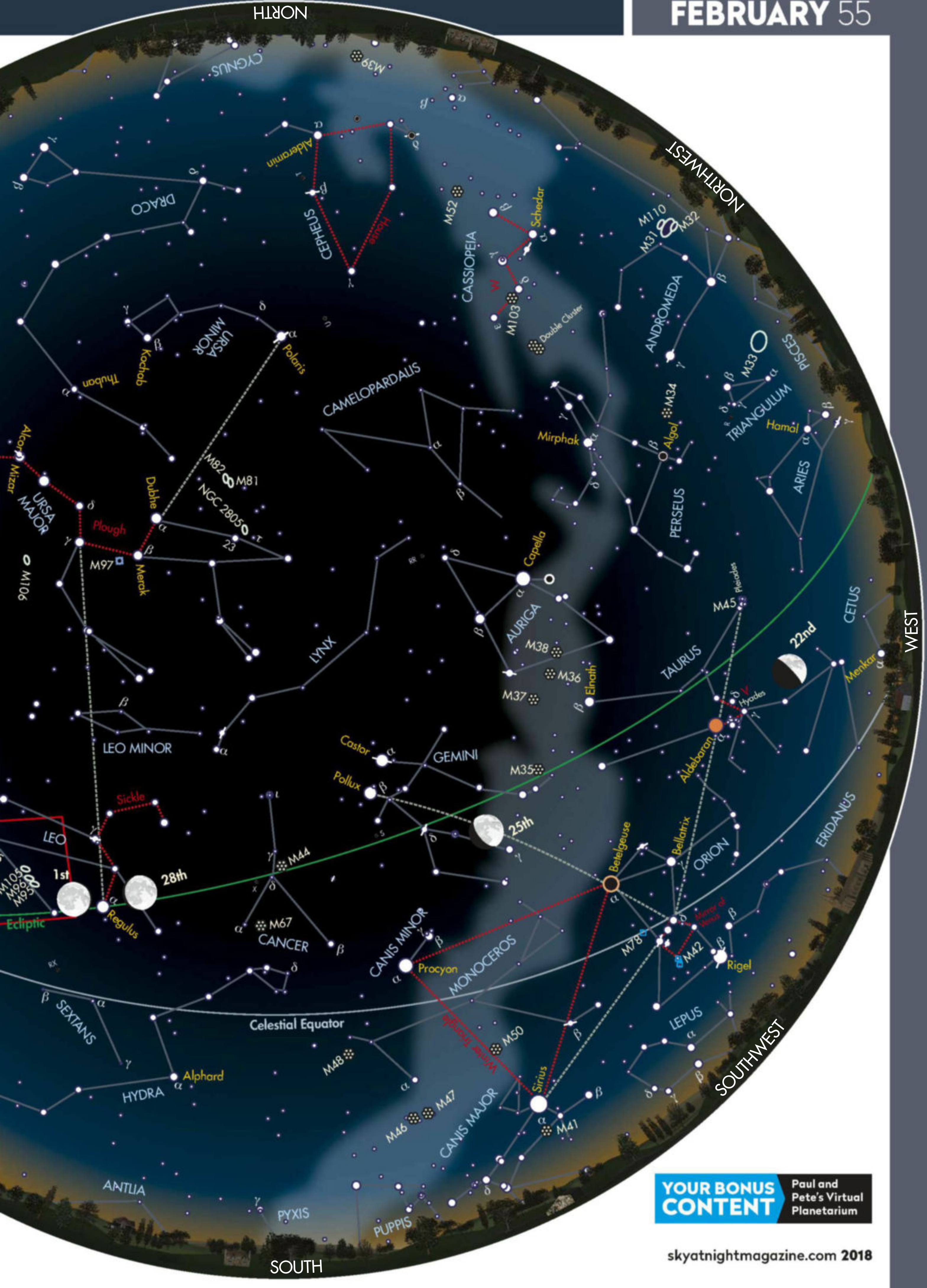
1 Feb 2018, 18:20 UT	17 Feb 2018, 08:17 UT
5 Feb 2018, 23:29 UT	21 Feb 2018, 09:45 UT
9 Feb 2018, 02:51 UT	25 Feb 2018, 12:16 UT
13 Feb 2018, 06:19 UT	1 Mar 2018, 17:10 UT

*Times correct for the centre of the UK

LUNAR PHASES IN FEBRUARY





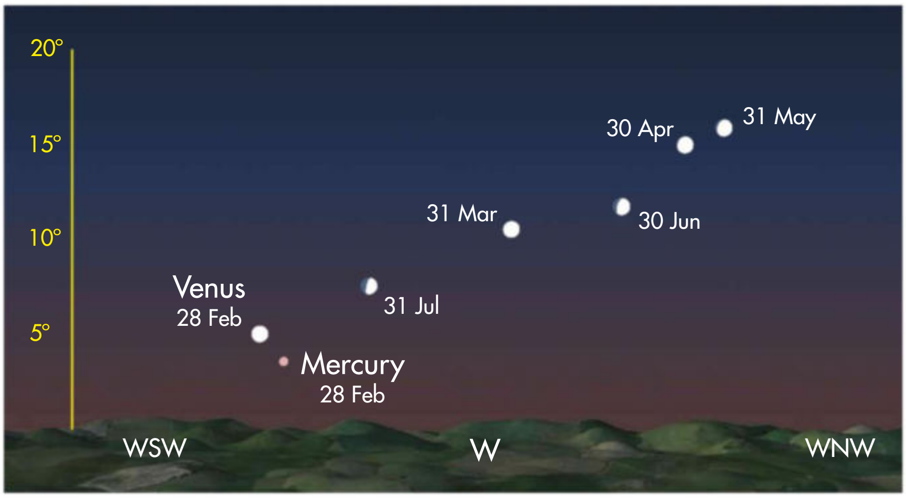

NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
CYGNUS
M39
DRACO
Alderamin
CEPHEUS
Garnet Star
M52
CASSIOPEIA
Schedar
W
M103
Double Cluster
M110
M31
M32
ANDROMEDA
PISCES
M33
TRIANGULUM
Hamal
ARIES
M34
Algol
Mirphak
PERSEUS
URSA MINOR
Kochab
Thuban
Polaris
CAMELOPARDALIS
Alcor
Mizar
URSA MAJOR
Plough
M82
M81
NGC 2805
23
Dubhe
Merak
M97
M106
Capella
AURIGA
M38
M36
M37
Elnath
M45
Pleiades
CETUS
22nd
Menkar
TAURUS
Hyades
Aldebaran
LYNX
LEO MINOR
Castor
Pollux
GEMINI
M35
Sickle
LEO
25th
M44
28th
1st
M105
M96
M95
Ecliptic
Regulus
M67
CANCER
CANIS MINOR
Procyon
Betelgeuse
Bellatrix
ORION
ERIDANUS
Mirror of Venus
M78
M42
Rigel
MONOCEROS
Celestial Equator
SEXTANS
LEPUS
Winter Triangle
M50
M48
Alphard
HYDRA
Sirius
M47
M46
CANIS MAJOR
M41
ANTLIA
PYXIS
PUPPIS

THE PLANETS

PICK OF THE MONTH

VENUS

BEST TIME TO SEE: 28 February, 30 minutes after sunset
ALTITUDE: 5° (low)
LOCATION: Capricornus
DIRECTION: West
FEATURES: Phase, subtle atmospheric markings
EQUIPMENT: 3-inch or larger scope



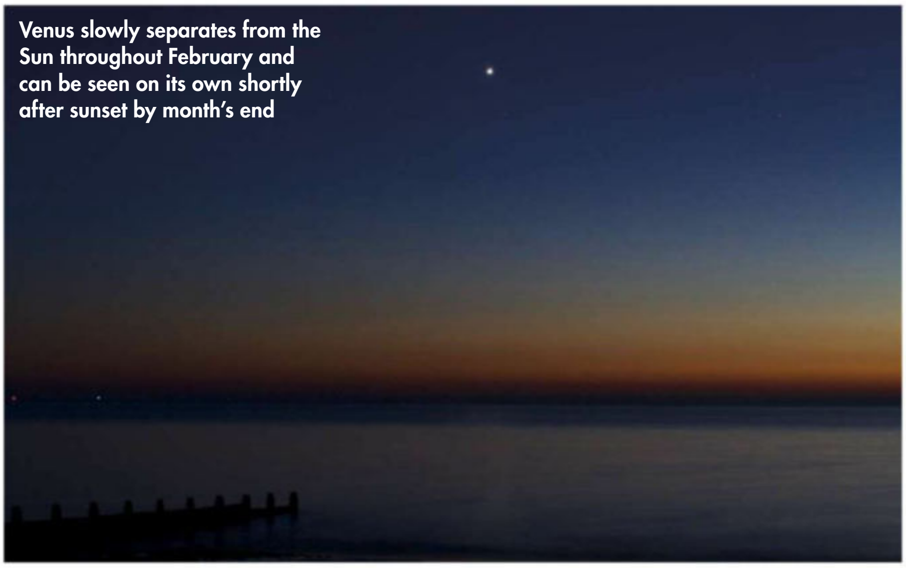
▲ **The position of Venus relative to the western horizon, 20 minutes after sunset over the coming months on the dates shown; the planet begins to sink lower after a peak in May**

Having passed through superior conjunction on 9 January, Venus is now technically an evening object, slowly increasing in apparent distance from the Sun. At the start of the month it appears separated from the Sun by a slim 6°, but this doubles to a more respectable 12° by 28 February. If you have a flat western horizon, it's an interesting exercise to see how early in the month you can see it after sunset. Be careful though and never sweep for Venus through binoculars or a telescope unless the Sun has set fully.

The position of Venus in the sky relative to the Sun is currently favourable and the planet remains reasonably high in the sky after sunset. Later in the year that will change, but over the next few months we will enjoy a view of this spectacularly bright planet against an ever-darkening evening twilight. This situation helps emphasise the planet's brilliance.

By the middle of the month, Venus is mag. –3.8 and sets 45 minutes after the Sun. It should be reasonably easy to spot around 20 minutes after sunset due to its extreme brilliance. On the evening of 16 February, Venus serves as a useful signpost towards an extremely thin lunar crescent. See page 52 for details of how to see it.

By the end of the month, the time difference between the sunset and Venus setting will have increased to just over an hour. On the 28th, mag. –3.8 Venus will appear close to its inner Solar System neighbour, Mercury. On this date Mercury will be shining at a respectable mag. –1.3, located 2.5° below and to the right of Venus, as seen from the UK.

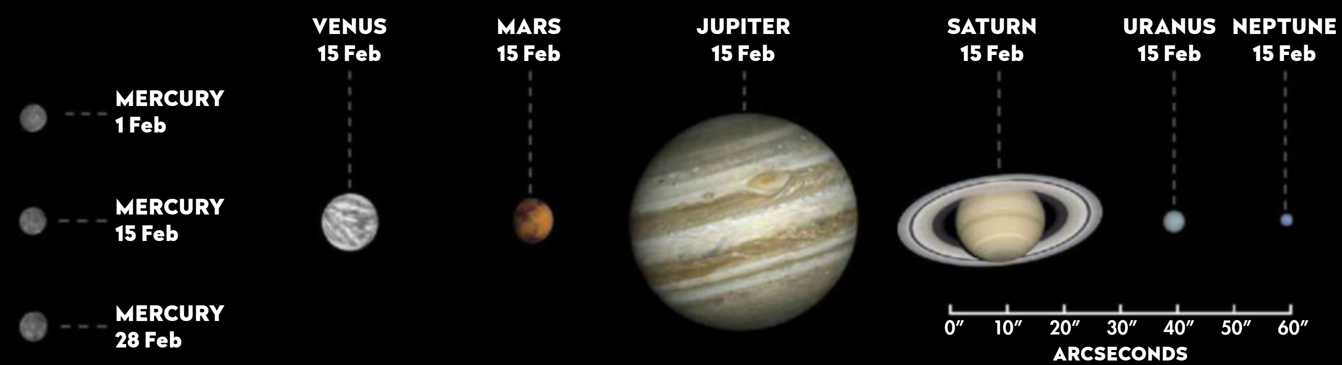


Venus slowly separates from the Sun throughout February and can be seen on its own shortly after sunset by month's end

PETE LAWRENCE X 3

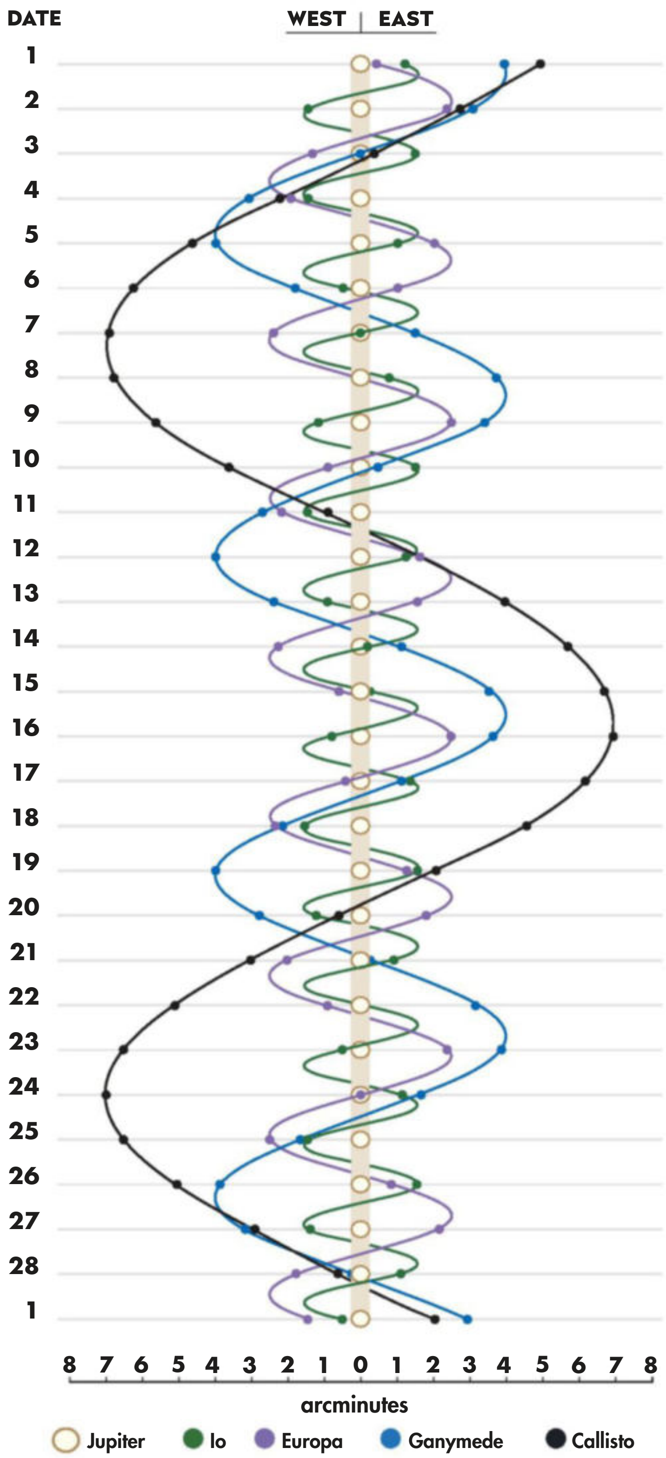
THE PLANETS IN FEBRUARY

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



JUPITER'S MOONS FEBRUARY

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



MERCURY

BEST TIME TO SEE: 28 February, 30 minutes after sunset
ALTITUDE: 3° (low)
LOCATION: Aquarius
DIRECTION: West

Mercury is in conjunction with the Sun on 17 February. This is a superior conjunction, meaning that the planet lines up with the Sun on the far side of its orbit. By the end of February, it may be possible to see Mercury briefly after sunset, as it appears to get closer to Venus in the evening twilight sky, low towards the west. On 28 February, Mercury shines at mag. –1.3.

MARS

BEST TIME TO SEE: 9 February, from 05:00 UT
ALTITUDE: 10°
LOCATION: Ophiuchus
DIRECTION: Southeast

Telescopically, Mars is a bit of a disappointment at present because it's a long way from Earth, only presenting a tiny, 5-arcsecond disc. But if you have clear skies on the morning of 9 February, set your alarm clock for a 5am start to see mag. +1.1 Mars just 5.4° above its celestial rival, mag. +1.0 Antares (Alpha (α) Scorpii). This is a great time to compare the red supergiant star with the Red Planet. Turn to page 53 for more details. On 9 February, the waning crescent Moon is 3.3° above Mars. By the end of the month, Mars will have passed across the southern region of Ophiuchus, ending up close to the Serpent Bearer's eastern leg. The planet will have brightened slightly to mag. +0.8 by 28 February.

JUPITER

BEST TIME TO SEE: 28 February, 05:00 UT
ALTITUDE: 19°
LOCATION: Libra
DIRECTION: South

Jupiter is located in the centre of Libra and visible in the morning sky. It just about reaches 20°, its highest point due south, as darkness lifts at the start of February. The last quarter Moon is close to Jupiter on the morning of 7 February and, as a slightly slimmer 44%-lit waning crescent, on the 8th. Catch them from around 04:00 UT. By the end of the month, Jupiter will be shining at an impressive mag. –2.0 and present a 38-arcsecond disc when viewed through a telescope. The planet now also manages to reach its highest point, due south, in darkness.

SATURN

BEST TIME TO SEE: 28 February, 05:15 UT
ALTITUDE: 6° (low)
LOCATION: Sagittarius
DIRECTION: Southeast

Saturn is in Sagittarius and this affects the planet's visibility. It can be seen low above the southeast horizon in the dawn twilight at the start of the month, slowly moving out of the Sun's morning glare to be visible in darker skies by the end of February. An 18%-lit waning crescent Moon sits close to it on 11 February. By 28 February, mag. +1.0 Saturn manages to creep up to about 8° in relative darkness, before the dawn twilight drowns it out.

URANUS

BEST TIME TO SEE: 1 February, 19:00 UT
ALTITUDE: 40°
LOCATION: Pisces
DIRECTION: Southwest

Uranus is now losing ground to the expanding evening twilight and only becomes visible when west of south at the start of the month. This reduces the maximum altitude the planet attains in a dark sky. By 28 February, the mag. +5.9 planet is almost above the western horizon by the time the sky becomes dark.

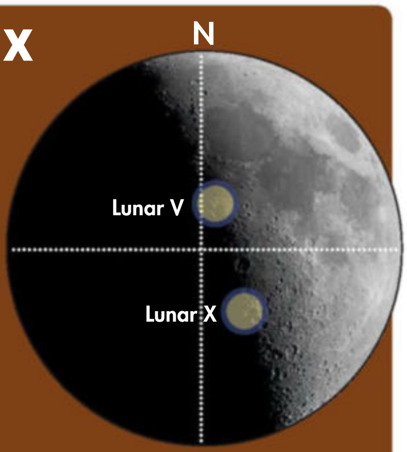
NOT VISIBLE THIS MONTH
NEPTUNE

YOUR BONUS CONTENT Planetary observing forms

MOON**WATCH**

THE LUNAR X

TYPE: Clair-obscur effect
SIZE: 65km (length of each 'X' diagonal)
LONGITUDE/LATITUDE: 1.1°E, 25.1°S
AGE: Between 3.9–4.6 billion years old
BEST TIME TO SEE: First quarter (22 February, from 16:30 UT)
MINIMUM EQUIPMENT: 2-inch refractor



The way the light from the Sun plays with features on the lunar surface is fascinating. When the light falls on areas of elevation or relief, shadows are created that give observers the impression they're seeing amazingly pointed mountains, suspended illuminated arcs and immense canyons.

Some of this light produces patterns that are reminiscent of more modest fare. The Lunar X is one example, appearing as large letter X suspended against the lunar night. Such creations are known as clair-obscur effects, literally 'clear-dark', referring to the play of light that tricks the eye into seeing something that isn't really there.

There are many clair-obscur effects visible on the Moon and most, like the Lunar X, are transient. To see them you have to observe within the short window when they are visible. In the case of the Lunar X, it takes approximately 2.3 hours for the feature to form. Low to medium magnification works best as this is less likely to emphasise the roughness created by smaller craters along the arms of the X. Once formed, the X remains visible for about an hour, taking a further 70 minutes to fade back into the lunar surface as it slowly illuminates. In total, the observing window lasts for 4.5 hours.

The X is formed when portions of the rims of craters La Caille (68km wide), Blanchinus (68km) and Purbach (118km) catch the Sun's light as the lunar dawn approaches. There is an element of luck required to see it: the Moon obviously needs to be above the horizon during the visibility period and the weather needs to be kind.

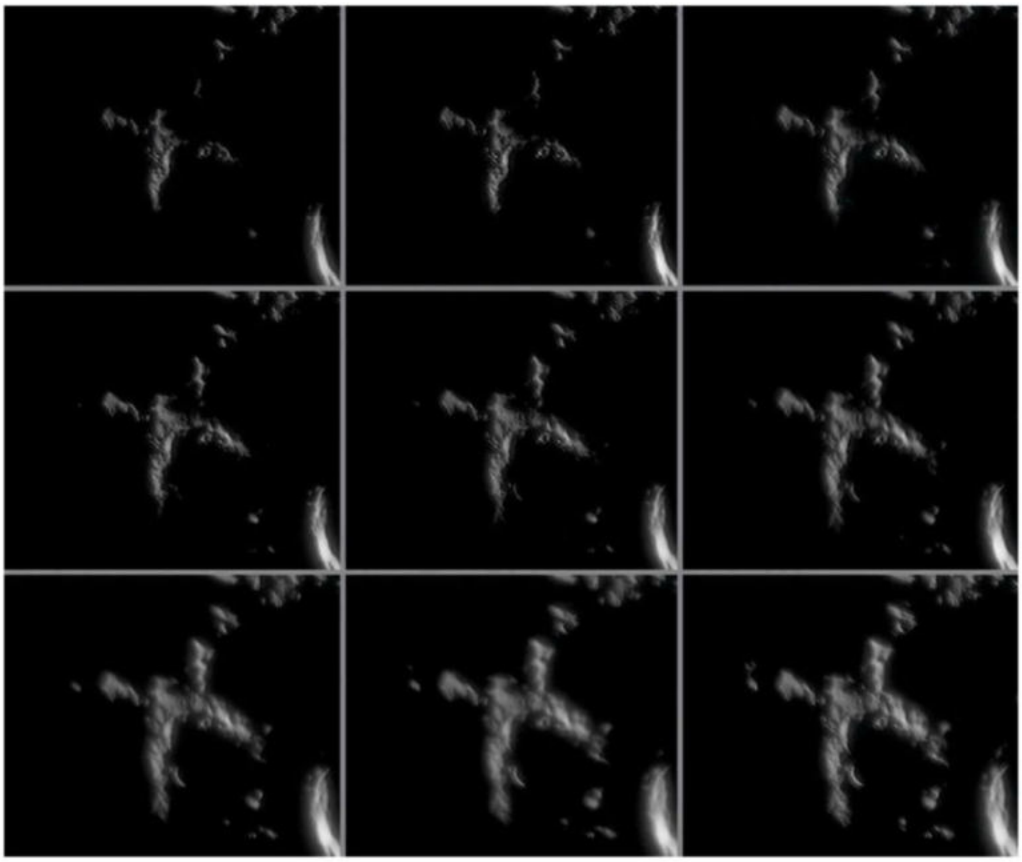
It is often stated that the X is visible at the first quarter phase but, being visible for such a short period, greater precision is necessary. A more reliable quantity is a value known as the lunar co-longitude. This describes the position of the morning terminator in degrees measured west of the Moon's central meridian.

The co-longitude is 0° at first quarter, 90° at full Moon, 180° at last quarter and 270° at new Moon. The X appears when the co-longitude value is at 358°. Various programs and apps can provide this information, including the excellent freeware Virtual Lunar Atlas (**www.ap-i.net/avl/en/download**).

There is an opportunity to see the X on the evening of 22 February. It will start to form from 16:10 UT when the Sun is still up, with the peak X visible around 18:30 UT as the sky is darkening. Look for it at a point roughly one-third of the way up the terminator from the Moon's southern limb. We've given the minimum equipment to see the lunar X as a 2-inch refractor, but it should be visible using tripod-mounted binoculars.

Once found, move your view further north and see whether you can find another famous clair-obscur effect known as the lunar V. This forms as elevated relief features close to the crater Ukert (23km) receive their first rays of sunlight from the approaching lunar dawn.

"In total, the observing window for the lunar X lasts for 4.5 hours"

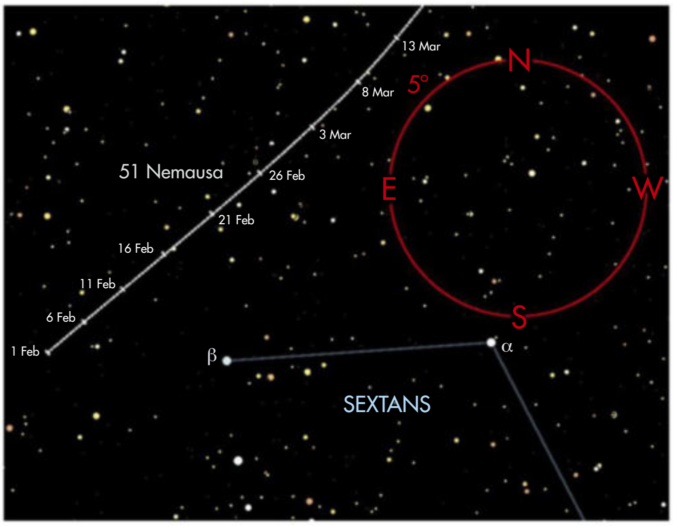


PETE LAWRENCE X 3

▲ **The Lunar X appears as sunlight passes over the nearly abutted rims of craters La Caille and Blanchinus**

COMETS AND **ASTEROIDS**

51 Nemausa – a carbon-heavy main belt asteroid travelling backwards across the sky



▲ **The faint stars Alpha and Beta Sextantis are your guides to finding the dark, carbonaceous asteroid 51 Nemausa**

Asteroid 51 Nemausa reaches opposition on 25 February, when it'll appear at mag. +9.8 in the faint constellation of Sextans, the Sextant. It's a member of the inner part of the main asteroid belt that lies between Mars and Jupiter, taking 3.64 years to complete a single orbit, and was discovered on 22 January 1858 by the French amateur astronomer Joseph Jean Pierre Laurent.

Laurent was fortunate enough to be left the use of the Nîmes residence of astronomer Benjamin Valz after the latter left to take up the post of director of the Marseille Observatory in 1836. Valz's appointment gave Laurent access to Valz's private observatory, and it was there that Nemausa was discovered. The asteroid is named after the Celtic deity Nemausus, the patron god of Nîmes during the city's Roman occupation.

The asteroid has a diameter of 147.9km and may have its own tiny moon. It's a C-type (carbonaceous) asteroid. In addition to rocks and minerals, C-type asteroids contain large quantities of carbon and so appear quite dark. They are also the most common type, accounting for around three-quarters of all known asteroids.

Locating Nemausa during February without the aid of a Go-To mount will be an interesting challenge as the asteroid is tracking against the stars of Sextans. This is a very indistinct constellation, the main pattern of which is identified by three rather faint stars, the brightest being mag. +4.5 Alpha (α) Sextantis. A handy way to locate Alpha Sextantis is to draw a line from mag. +3.5 Eta (η) Leonis through mag. +1.4 Regulus (Alpha (α) Leonis), extending it for approximately 2.5 times to the south. This takes you directly to Alpha Sextantis. From there, locate mag. +5.1 Beta (β) Sextantis, 5.5° to the east. Using these two stars as a reference, you should be able to use our chart (left) to locate Nemausa from here.

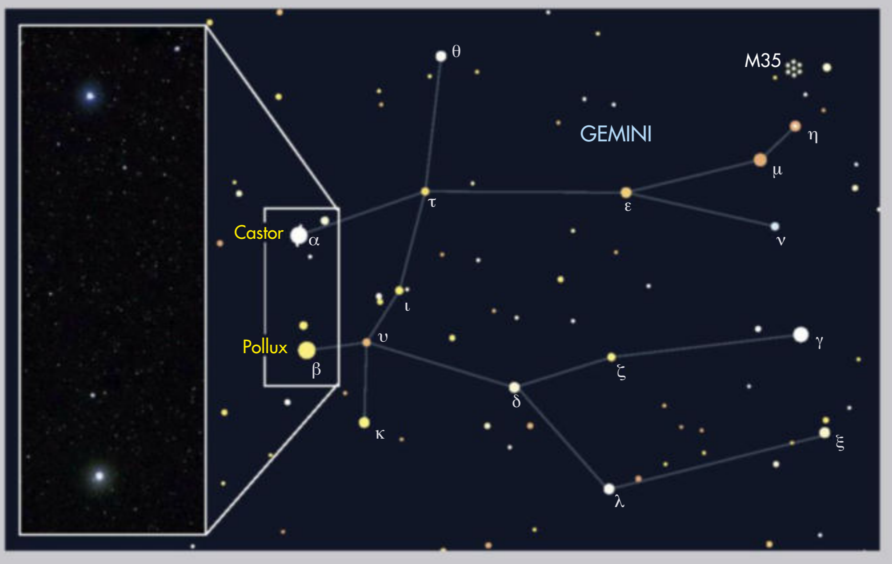
At the start of February, Nemausa appears at mag. +10.6. It slowly brightens as the month progresses, reaching its opposition magnitude of +9.8 on 25 February, and it remains at this brightness until the end of the month.

STAR OF **THE MONTH**

Castor – a complex Twin made up of three pairs

Castor (Alpha (α) Geminorum) is one of the two Twin stars in Gemini, the other being Pollux (Beta (β) Geminorum). It is the most northern of the pair and its twin status is mythological rather than physical – Castor being the mortal twin of immortal Pollux in legend. Visually, Castor is dimmer and more yellow than orange Pollux.

What looks like a single star to the naked eye is in fact a complex multiple star. With a magnification of 100x, a 3-inch or larger scope should split Castor into two similar-looking stars, one mag. +1.9 (Castor A) and the other mag. +3.0 (Castor B). The separation has increased from 2 arcseconds in 1970 to 6 arcseconds today. Their orbital period is 445 years, the orbital plane being tilted to our line of sight by 25°. A third companion, Castor C, appears 1.2 arcminutes to the south, and although it's much dimmer at mag. +9.1 it remains an easy target for small telescopes.



▲ **Castor is actually a system of three spectroscopic binary stars that lies 51 lightyears from Earth**

Each of the three components is a spectroscopic binary, a gravitationally bound pair so close that we can only determine its true nature by spectroscopy. The total star count in the Castor system is six. The average distance between Castor A and B is 104 AU, varying between 71 and 138 AU.

The main components of A and B are 37 and 13 times more luminous than our Sun, and 2.4 and 1.9 solar masses respectively. The close, spectroscopic companions are likely to each be half as massive as the Sun.

Castor C is orientated to Earth such that its light is eclipsed by its two companions. This makes it an eclipsing spectroscopic binary. Also known by the variable star name YY Geminorum, it's comprised of two red dwarfs with an orbital period of 19.54 hours.

STEPHEN TONKIN'S

BINOCULAR TOUR

February brings a dog hiding in the Bull, an eclipsing binary and overshadowed clusters

☑ Tick the box when you've seen each one

1 DAVIS'S DOG

10x50 Identify mag. +3.5 Oculus Boreus (Epsilon (ε) Tauri) and navigate 3° in the direction of the Pleiades, where you will find mag. +4.9 Omega^2 (ω^2) Tauri. This is the nose of the most dog-like of canine asterisms. It consists of 15 or so stars of mag. +8.0 and brighter, and spans a region of about 3.5x1.5°. Three brighter stars form its head, and a string of four that includes the wide double of mag. +4.2 Kappa^1 (κ^1) and mag. +5.1 and Kappa^2 (κ^2) Tauri make its tail. Its short legs are made of fainter stars. ☐ **SEEN IT**

2 HU TAU

10x50 HU Tauri is an eclipsing binary slightly less than 3° northeast of Oculus Boreus. It dips most in brightness when the fainter star passes in front of the brighter one. During these primary eclipses, which last about seven hours, it dims from mag. +5.9 to mag. +6.7. The period is 2.0563 days, which means that, every second day, the eclipse will be 81 minutes later. The first fully observable eclipse this month will be on the 1st, with mid-eclipse at 21:37 UT; the last will be on the 12th, with mid-eclipse at 04:22 UT. ☐ **SEEN IT**

3 LEAPING MINNOW

10x50 Our second asterism of the month is just over 4° east of mag. +2.7 Hassaleh (Iota (ι) Aurigae). Here you will find a little group of 5th-magnitude stars, just over 1° long. Among them are 14, 16, 17, 18 and 19 Aurigae. In a pair of 10x50 binoculars you should see that this group of stars forms the shape of a fish – the Minnow. If you look to the northeast of the Minnow you will see the 'Splash', which includes mag. +5.0 Phi (ϕ) Aurigae. If you count the splash, you should see at least 30 stars. ☐ **SEEN IT**

4 A TRIO OF CLUSTERS

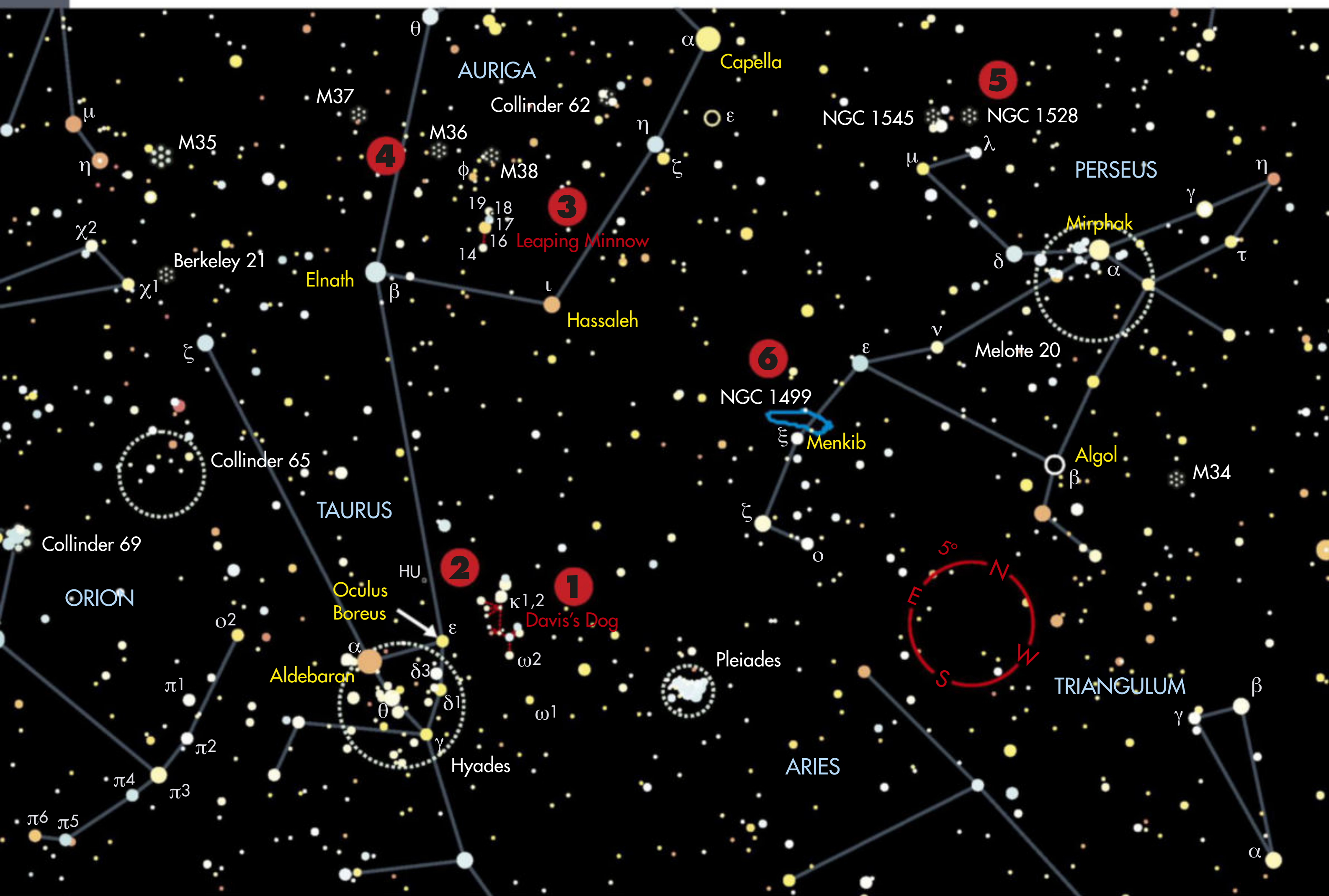
10x50 Put Phi Aurigae at the bottom of the field of view and you should see two fuzzy patches, to the left and right of the centre respectively. The right-hand, larger and fainter one is M38, the one on the left M36. Now put M36 at the right edge of the field and another fuzzy patch, larger and brighter than either of the previous two, will be visible to the left of centre. This is M37 which, at a distance of nearly 4,500 lightyears, is 500 lightyears farther away than the other two. ☐ **SEEN IT**

5 THE OTHER DOUBLE CLUSTER

15x70 Perseus has two double clusters, both discovered by William Herschel. This less famous one is arguably the more interesting of the two, owing to the contrast between the clusters. Look mid-way between mag +0.1 Capella (Alpha (α) Aurigae) and mag. +1.8 Mirphak (Alpha (α) Persei); the more obvious of the pair, NGC 1528, should be visible as a rich, compressed cluster, much like M38. The companion, just over 1° to the southeast, is smaller and sparser, but slightly brighter. ☐ **SEEN IT**

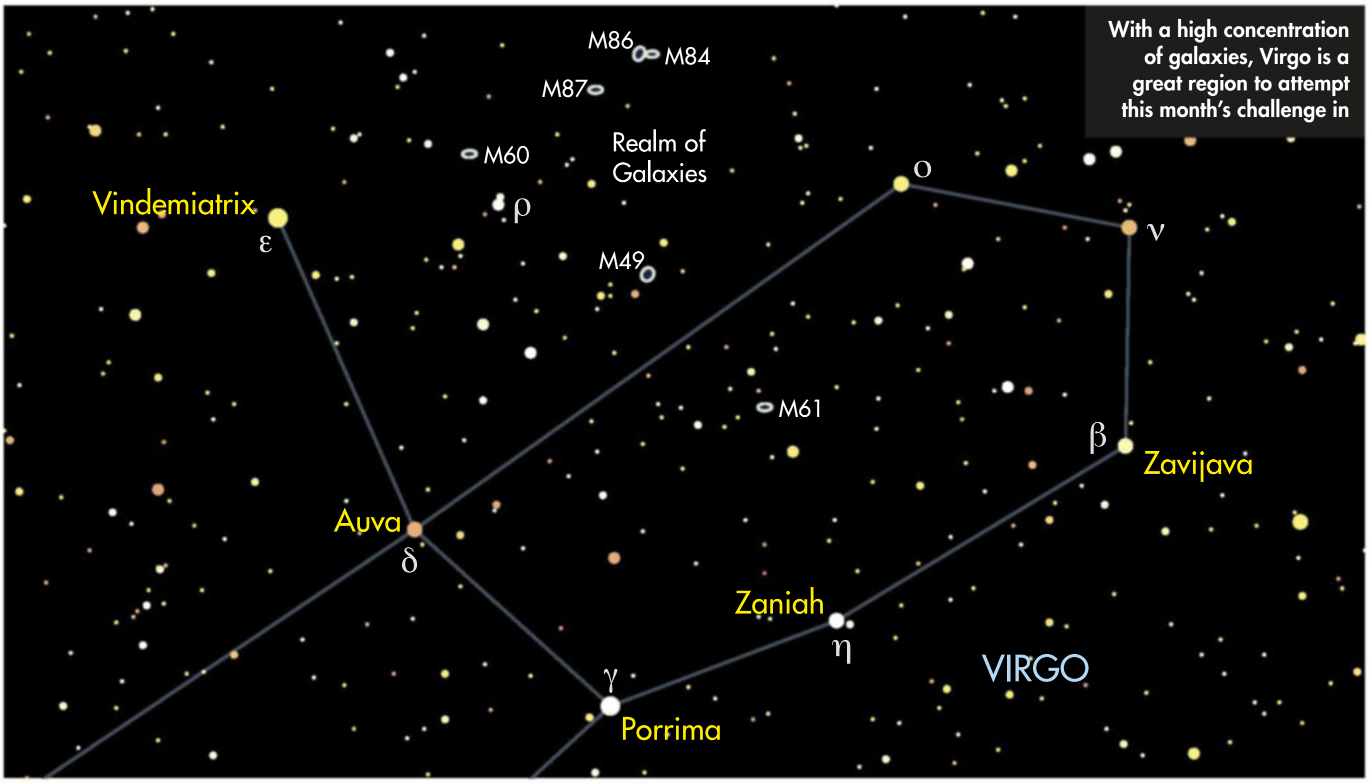
6 CALIFORNIA NEBULA

15x70 We end with a challenge that requires a dark, transparent sky and mounted binoculars. Place mag. +4.0 Menkib (Xi (ξ) Persei) mid-way between the centre and the bottom edge of the field of view. Use averted vision and look for a variation in sky-brightness, with an elongated brighter patch crossing the central half of the field of view. This is the California Nebula, NGC 1499. If you are lucky enough to have a very dark site, you may find it easier in 10x50 or even 8x40 binoculars. ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

What's the dimmest galaxy you can see with a pair of binoculars?



With a high concentration of galaxies, Virgo is a great region to attempt this month's challenge in

As the bright constellations of winter slowly drift west, they are replaced by the more subtle patterns of spring. The relatively local deep-sky objects that pepper the winter constellations also give way to more distant fare in the form of galaxies. This month our challenge is to find the faintest galaxy you can see through a pair of binoculars.

As ever, such a relatively straightforward question turns out to be nothing of the sort. Take, for example, M31, the Andromeda Galaxy. This is best seen early evening in the west and at mag. +4.5 really doesn't pose much of a problem for binoculars. Nearby sits M33, the Triangulum Galaxy, which has a slightly fainter but still binocular-friendly magnitude of +5.7. Except, where M31 is relatively easy, M33 is quite difficult. In both cases the part of the galaxy you stand a chance of seeing is the bright core. Both M31 and M33 are spiral galaxies tilted at different angles to our line of sight, M31 at 15° and M33 at 54°. The more oblique tilt of M31 helps it maintain brightness while the more face on view of M33 spreads its light over a larger area resulting in a lower surface brightness.

As well as visual magnitude, a galaxy's type and apparent size are important. For spirals and lenticulars, tilt also makes a difference. Taken together, these values define the galaxy's surface brightness and this is what determines its visibility. Listed magnitudes assume an object is a point source. Surface brightness takes the size of an object into account, its magnitude being spread across its area.

To start, try the galaxies described in our Deep-Sky Tour on page 62. M65 and M66 in Leo are definite binocular candidates under a dark sky.

OBJECT	SIZE (ARCMINUTES)	MAG.	SURFACE BRIGHTNESS	CONSTELLATION
M66	9.1x4.1	+8.9	+12.7	Leo
M105	5.3x4.8	+9.5	+12.8	Leo
M65	9.8x2.9	+9.2	+12.8	Leo
M51	11.2x6.9	+8.1	+12.9	Canes Venatici
M60	7.6x6.2	+8.8	+12.9	Virgo
NGC 5195	5.9x4.6	+9.6	+12.9	Canes Venatici
M84	6.5x5.6	+9.2	+13.0	Virgo
M87	8.3x6.6	+8.6	+13.0	Virgo
M96	7.8x5.2	+9.3	+13.1	Leo
M49	10.2x8.3	+8.3	+13.2	Virgo
M86	8.9x5.8	+8.9	+13.2	Virgo
M61	6.5x5.9	+9.3	+13.4	Virgo
NGC 3628	13.1x3.1	+9.6	+13.4	Leo
M95	7.4x5.0	+9.8	+13.5	Leo

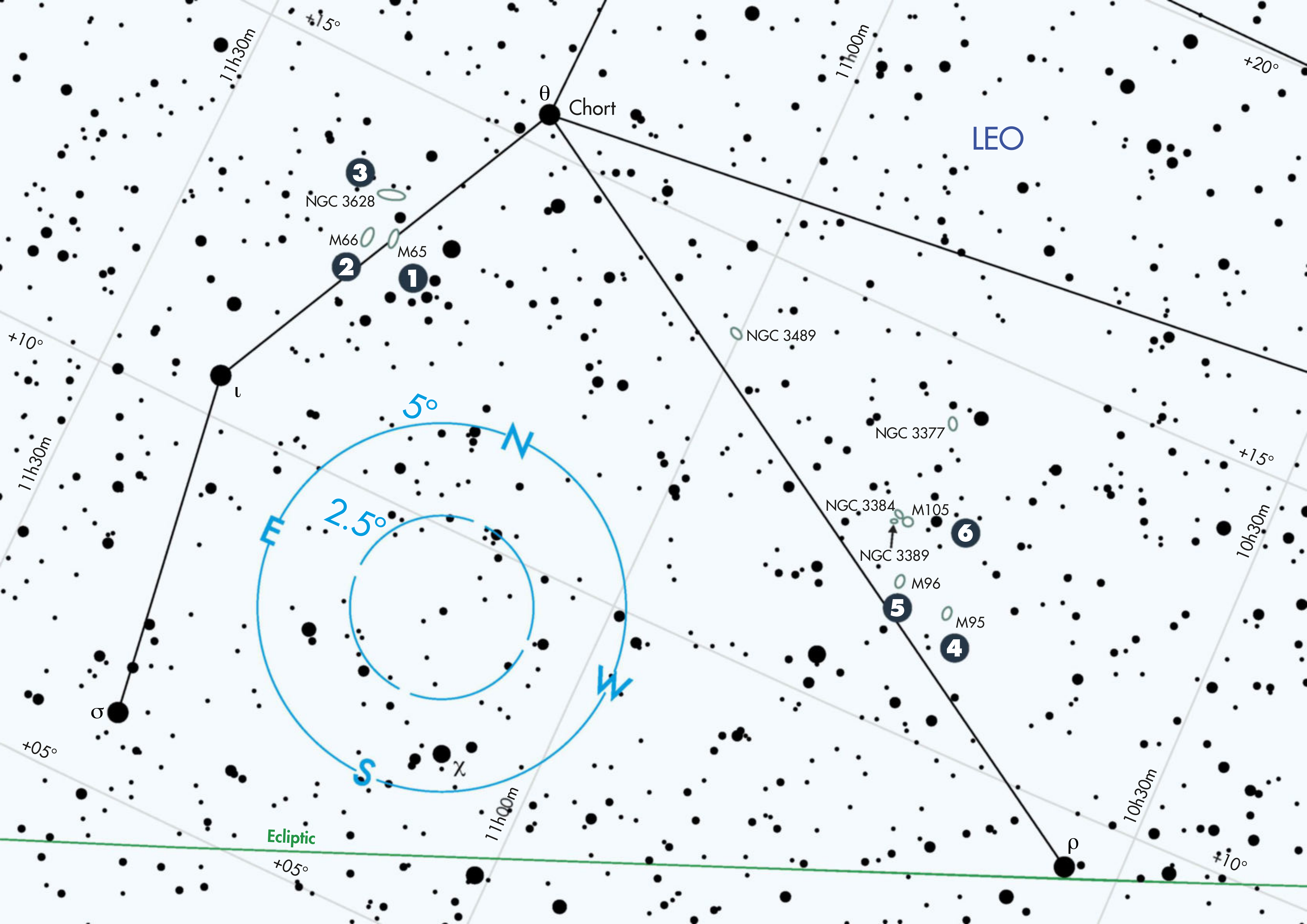
▲ Table of some of the brighter galaxies ordered by surface brightness; surface brightness is measured in magnitudes per square arcminute

The M95 group (again in Leo) is harder and more convincingly seen with larger binoculars. The famous Whirlpool Galaxy, M51 in Canes Venatici, is linked to an adjoining galaxy, NGC 5195. M51 is mag. +8.1 and the companion +9.6, but because the companion's size is so much smaller than M51, both objects have the same surface brightness.

Next door to Leo is Virgo, and within the asterism known as the Bowl of Virgo lies the region known as the Realm of Galaxies. Here, you'll find many galaxies clustered into a relatively small part of the sky. This makes them perfect for you to practice galaxy hopping and test your binocular skills to see just how faint you can go.

If you struggle with one set of binoculars, see whether you can obtain a larger pair and repeat the test. Make a note of the faintest galaxy seen and whether you can beat this under better sky conditions. Placing binoculars on a sturdy mount may help you go even dimmer.

PETE LAWRENCEX3


LEO
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NGC 3628
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NGC 3377
NGC 3384
M105
NGC 3389
M96
M95
5°
2.5°
N
E
S
W
Ecliptic
11h30m
11h00m
10h30m
+20°
+15°
+10°
+05°

DEEP-SKY TOUR

Get ready for a spot of galaxy hunting as we turn to the legs of Leo

☑ Tick the box when you've seen each one

1 M65

M65 is a mag. +9.3 spiral galaxy in the back leg of Leo, halfway between mag. +3.3 Chort (Theta (θ) Leonis) and mag. +6.6 Iota (ι) Leonis. It's an easy target through a small instrument thanks to its bright core. A 6-inch scope shows the core as elongated, approximately 5x1 arcminutes in size. A 10-inch scope shows a compact and bright central core region, with a dimmer haze extending out to a size of 8x2 arcminutes. The long axis of the galaxy is almost north-south aligned. A dark lane runs along the eastern side of the core but this is a struggle with a scope under 12 inches in aperture. ☐ **SEEN IT**

2 M66

M66 is easy to find from M65, being just 20 arcminutes to the east-southeast. This galaxy is also slightly easier to see as it's marginally brighter. M66's listed magnitude is +8.9 making it an excellent galaxy for smaller instruments. Again, there's a bright core, but the outer halo appears more diffuse than M65. M66 has the guise of an elongated smudge, orientated close to the north-south direction and fairly mottled. In a 10-inch instrument, the core is like a thin needle of light, 2x0.25 arcminutes in size. The outer halo extends to 5x2 arcminutes. Through larger apertures, the unwinding spiral arms surrounding the core appear to bring the galaxy to an abrupt end at its northeast and southwest extremities. ☐ **SEEN IT**

3 NGC 3628

M65 and M66 are two members of the Leo Triplet. The third member, spiral galaxy NGC 3628, is harder to see. That's because it's dimmest at mag. +9.6, and has a larger apparent size and lower surface brightness. It can be found 37 arcminutes north of M66. A 10-inch scope shows an elongated and delicately thin object, 10x1 arcminutes in size, orientated east-west. A 12-inch instrument shows that the core is offset to the north of the centre. Long exposure images, meanwhile, reveal a rectangular shape with a central dark dust lane running along the main axis, giving it a resemblance to a hamburger. Unsurprisingly it's also known as the Hamburger Galaxy. The Leo Triplet as a whole is also known as the M66 Group, and is approximately 35 million lightyears from Earth. ☐ **SEEN IT**

4 M95

We need to differentiate Leo's back legs for our next target, the barred spiral galaxy M95. While the Leo Triplet are within the Lion's rear back leg,

◄ **M95 is a barred spiral galaxy some 38 million lightyears away**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

M95 is located a little north of the position two-thirds of the way along the foremost back leg, which runs from Chort to mag. +3.8 Rho (ρ) Leonis. M95 is listed at mag. +9.8 but, thanks to its 2.0x2.5-arcminute size and its resulting surface brightness, through a 10-inch scope it appears only slightly fainter than M66. Where M65 and M66 have elongated cores, M95's core appears almost stellar. A 12-inch scope shows it with definite size and elongated. The rapidly fading outer halo also appears unevenly lit through a large aperture. ☐ **SEEN IT**

5 M96

M96 is 41 arcminutes to the east and a fraction north of M95. It's brighter than M95 at mag. +9.3, and despite its larger overall apparent size of 7.5x5 arcminutes, this intermediate spiral galaxy maintains a decent surface brightness. This is a galaxy with a mass and size not dissimilar to that of our own Milky Way. A small instrument shows a diffuse halo with a brighter core. A 10-inch scope shows the outer halo to be elongated with a southeast-northwest orientation. Using this aperture size reveals an object roughly half the apparent size of M95, with a star-like core. Larger apertures at high magnifications show the core to have size and the outer halo to be non-uniform in brightness. ☐ **SEEN IT**

6 M105

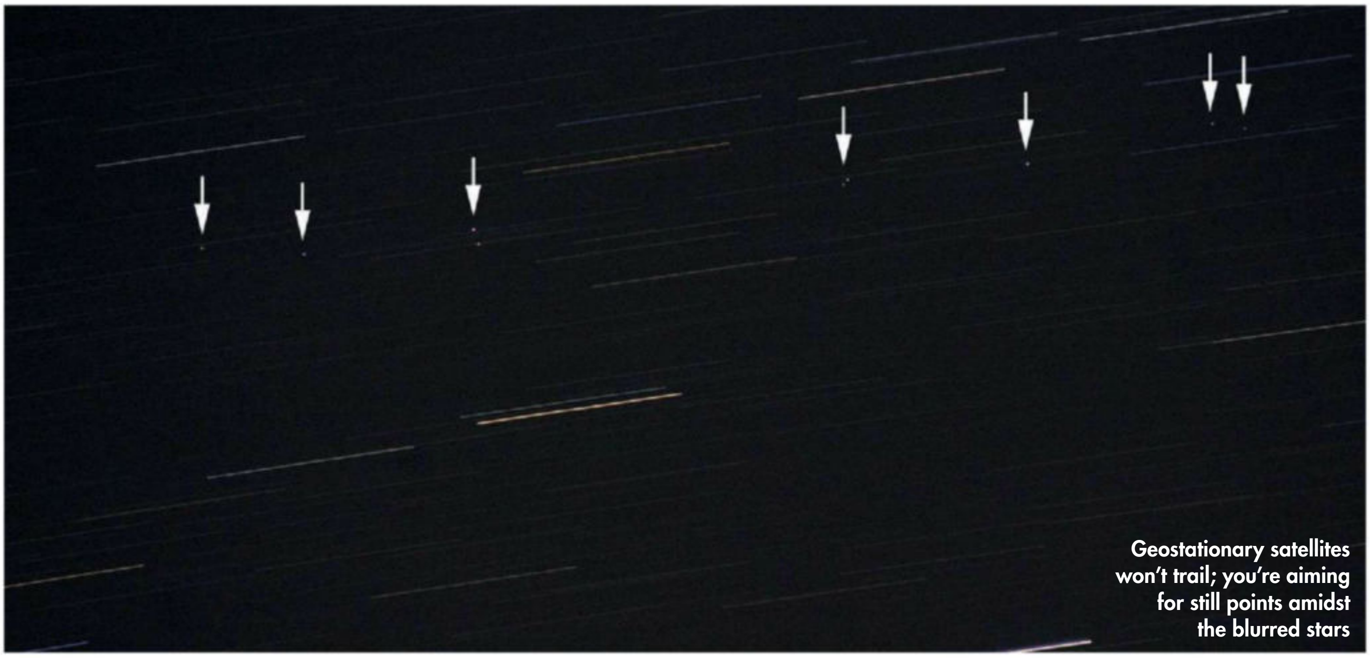
Our final target is the mag. +9.5 elliptical galaxy M105, which along with M96 is part of the M95 Group. At least nine additional galaxies belong to this group. Low magnifications show M95, M96 and M105 in the same field, M105 being 48 arcminutes north and slightly east of M96. A 6-inch scope shows a star-like nucleus centred within a glowing circular haze. The halo appears elongated through larger instruments. Mag. +9.9 NGC 3384 is another elliptical galaxy, 7.5 arcminutes east-northeast of M105, with a similar, albeit smaller, appearance. Larger-aperture instruments show NGC 3384 to be more elongated. Spiral galaxy NGC 3389 sits 6.5 arcminutes southeast of NGC 3384, though at mag. +11.8 it is much harder to detect than the others. ☐ **SEEN IT**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: JOHANNES SCHEDLER/CCDGUIDE.COM

ASTROPHOTOGRAPHY



Geostationary satellites won't trail; you're aiming for still points amidst the blurred stars

Geostationary satellites

RECOMMENDED EQUIPMENT

DSLR, fixed tripod, remote shutter release cable

Unless you have a permanent observatory, polar alignment can be a bit tiresome. Even a tiny misalignment with the celestial pole can be enough to cause stars to trail on long exposure photographs. Effort and diligence pays off but it's also nice to have the opportunity to attempt something that doesn't require so much effort.

Star trails are a good example. Set the camera's sensitivity relatively low, focus at infinity and, with a camera mounted on a fixed tripod, a multi-minute exposure will show the stars' motion across the sky. Of course, the real reason they trail isn't because they are moving at all, but rather because Earth is rotating beneath them.

And it's here that this month's imaging target comes to the fore. Geostationary satellites are man-made spacecraft placed in a special above the surface of Earth.

As orbital height increases, a body will travel slower and take longer to complete each orbit. The ISS orbits at an average height of 408km and a speed of 27,600km/h. At this pace it takes approximately 92 minutes to circle Earth once. If you gave the ISS a height boost, increasing the size of its orbit by 87.7 times, it would be at a distance of 35,786km and travelling at the slower speed of 11,052 km/h. This would increase its orbital period to 1,436 minutes or one sidereal day. To be useful, this fictitious adjustment to the ISS's orbit would also require the orbit's inclination to be reduced from its current value of 51.64° to 0° along Earth's equatorial plane.

Any satellite placed in such an orbit would effectively be aligned with a static point on Earth's equator, passing around its orbit at the same rate at which Earth rotates below it. This is what a geostationary satellite does.

This is a valuable position to have and is used for all manner of purposes – from communications to meteorological imaging and military surveillance. Despite the geostationary orbit being 265,000km in circumference, only a certain number of geostationary 'slots' are defined. This is to prevent issues such as radio-frequency interference.

The tug of the Sun and the Moon, combined with other effects such as a slight asymmetry in the shape of Earth and the influence of the solar wind, causes the satellites to drift out of position. Accordingly, small manoeuvres are required from time to time to maintain a satellite's position inside its slot. From the ground the satellite appears like a fixed star in the same place relative to your horizon. Most appear to shine between 10th and 12th magnitude, but some can flare to binocular brightness, even becoming visible to the naked eye on rare occasions.

Flares are more likely to be seen close to Earth's equinoxes in late March and late September. At these times the Sun lines up with Earth's equatorial plane, optimising its position for flaring. Another interesting effect can occur around the equinoxes because the Sun's alignment puts geostationary satellites within reach of Earth's shadow.

KEY TECHNIQUE

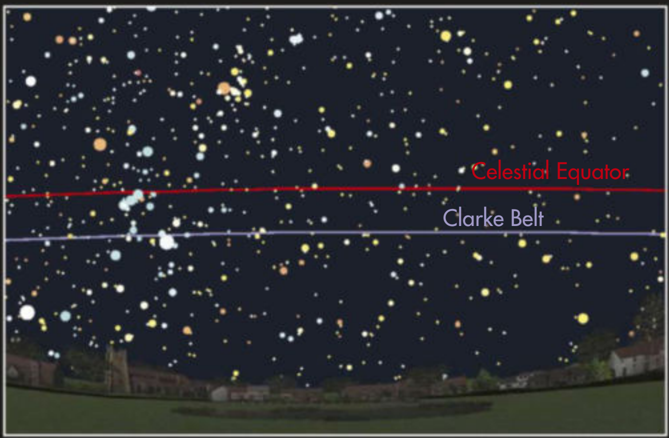
THE RIGHT EXPOSURE

Most of the time long-exposure imaging requires lots of effort to be expended in polar aligning an equatorial mount. Only then can a telescope, or camera, track the stars and keep them as pinpoints. However, geostationary satellites are different: they move with Earth's rotation, retaining their position in the sky relative to the horizon. Imaging them requires you to know where to find them and how long an exposure to use so you don't lose them against the stars trailing across your image.

ALL PUCTURES: PETE LAWRENCE

Send your image to: hotshots@skyatnightmagazine.com

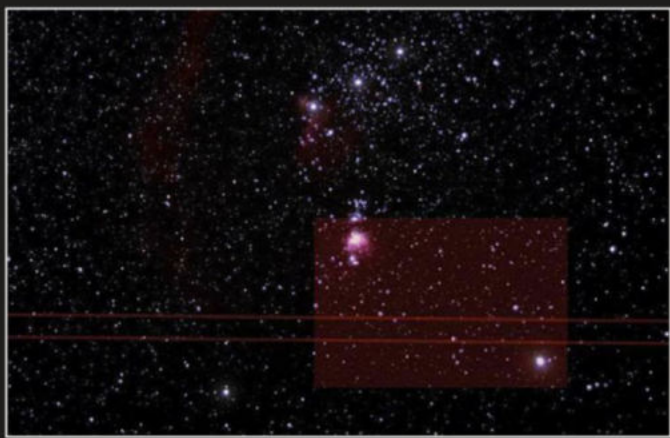
STEP BY STEP



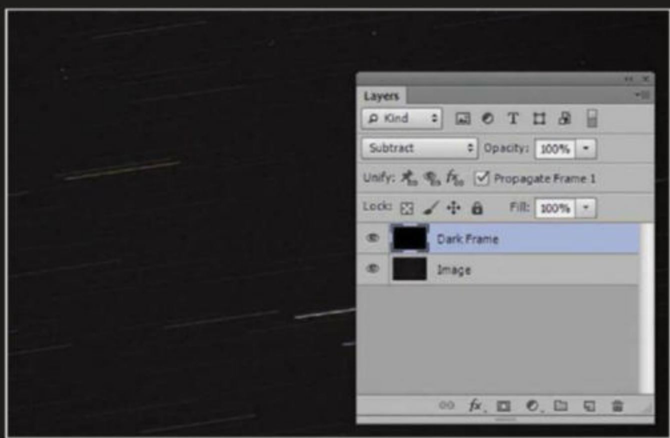
STEP 1
The orbital ring occupied by geostationary satellites is sometimes referred to as the Clarke Belt or Clarke Orbit, after the science fiction author Arthur C Clarke who first spread the idea about how such an orbit could be used. From the UK, the Clarke Belt appears as an arc between 7.4° and 7.9° south of the celestial equator.

STEP 2
A DSLR fitted with a 100-200mm lens is ideal for capturing geostationary satellites. The lens should be set to manual focus and pre-focused at infinity. The camera should be set to bulb mode. This will typically be via a 'Bulb' exposure setting when the camera is set to manual (M) or via a dedicated B setting on the camera's mode dial. Consult your camera's instructions if you're not sure.

STEP 3
A remote shutter release is required. This will allow you to keep the camera's shutter open for longer than the maximum value normally permitted by the camera's in-built exposure range. Set the ISO to 200-400 and the lens f/number a couple of stops above its lowest value. Anything around f/4 should be fine. Finally, with everything set as described, attach the camera to a fixed tripod.



STEP 4
Use a planetarium program such as Stellarium or Cartes du Ciel (both free) to identify stars with declinations close to, or within the range 7.4° to 7.9° south; for reference, mag. +0.2 Rigel (Beta (β) Orionis) has declination 8.2° south, and a 200mm lens attached to a non-full frame DSLR has a field of view of 6.3x4.2°.



STEP 5
The CalSky website (www.calsky.com) is excellent for identifying satellites. Input your location and navigate to the 'satellites-geostationary' page. Adjust date and time options to generate a list of visible satellites with azimuth and altitude positions. Use the same date and time values in a planetarium program to identify the stars close to these satellites.

STEP 6
Your exposures should be long enough for stars to trail but not so long that the trails hide the satellites. Try exposing for two, five, 10 and 15 minutes to see what works best for your sky conditions. Repeat with the lens cap fitted and subtract this dark frame to remove any hot pixels. Any points of light left amongst the trails should be geostationary satellites.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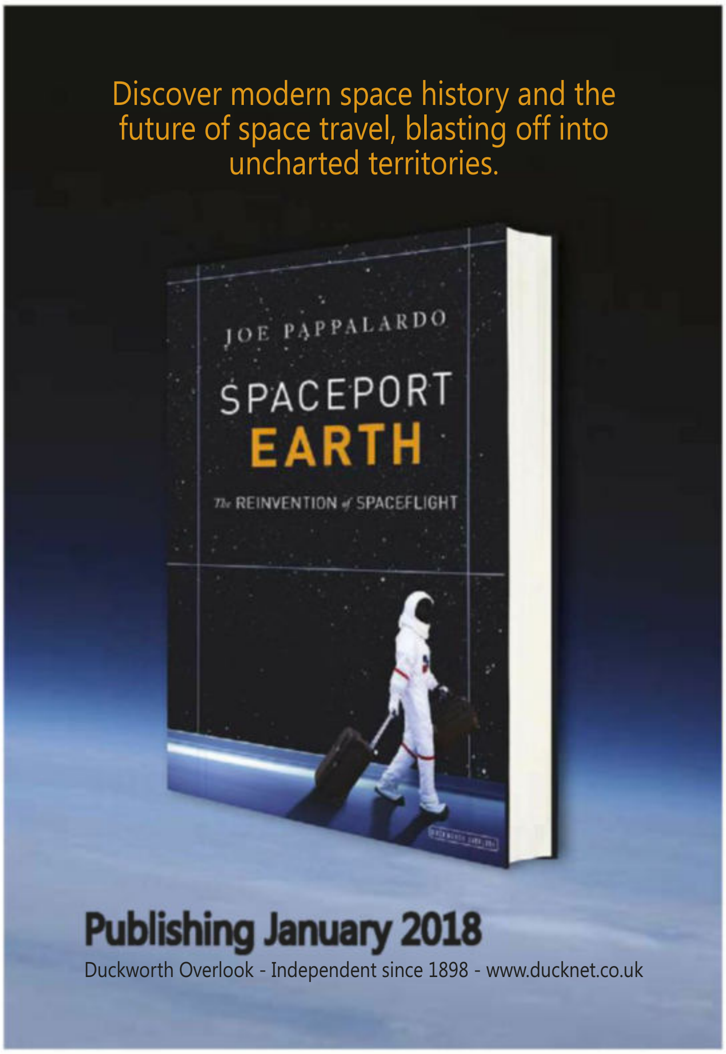
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INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

2018 marks the 10th instalment of the world's premier astrophoto competition

It's time to select your best images of the night sky and enter them into the Insight Astronomy Photographer of the Year 2018 competition (IAPY). Whether you're a seasoned astro imager or someone who snaps the night sky with a smartphone, IAPY is open to all.

Sponsored by Insight Investment since 2015, this year's competition will see the overall winner take home £10,000, with prizes of £1,500, £500 and £250 for category winners, runners-up and highly commended entries. There are also two special categories, with prizes of £750 each.

While in previous years the winning images have been showcased in an exhibition at the Royal Observatory Greenwich's Astronomy Centre, this year IAPY will celebrate the 10th competition with a special, expanded exhibition in a larger gallery within the nearby National Maritime Museum; an IAPY retrospective that will not only feature the 31 prize-winning images from 2018, but also 69 of the best entries from previous years.

Over the next two pages, we reveal the eight categories and special prizes that make up this year's competition, so read on, get inspired and get snapping! ▸

CELEBRATING 10 YEARS

KAMIL NUREEV

Auroral rays arc over the forested Siberian tundra in this shot by Kamil Nureev of Russia – a worthy runner-up in 2017's Aurorae category

2018 MAIN CATEGORIES

Aurorae

Aurorae make for some of the most impressive astrophotos, as they allow photographers to set wisps of bright colour against inky black skies. Capture a green glow that will really wow this year's judges.

People and Space

This category is all about the relationship between humanity and the night sky, and the wonder it continues to ignite in us. If your astrophoto features a human figure or signs of civilisation, this one's for you.

ENTER FROM 15 JAN

Dates for your diary

Competition opens for submissions: 15 January
Submission closing date: 9 March
Exhibition opens: 24 October

How to enter and rules

To put your yourself in the running to become the next Insight Astronomy Photographer of the Year, and to read the full terms and conditions, visit the competition website: www.rmg.co.uk/astrophoto

Skyscapes

Any astro image featuring an Earthly foreground can be entered into this category. Capture the union between our planet and a starry night sky to show the relationship between the terrestrial and celestial.

Stars and Nebulae

Multicoloured deep-sky objects, crisp globular clusters and star trails: there is no shortage of targets that would suit this popular category. Take a photo of your favourite deep-sky object and enter it here.

Galaxies

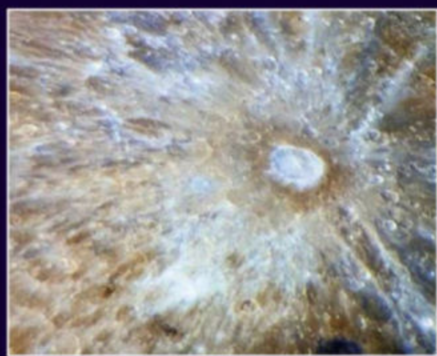
There are trillions of galaxies to choose from, so this is a category that allows photographers to really get creative. Impress this year's judges with the fine, crisp detail of a spiral or the glow of an elliptical.

Our Sun

From a stunning solar disc to close-ups of flares, sunspots and prominences, there are numerous ways to celebrate our closest star to reveal its intricate features and active, dynamic surface. Or perhaps you witnessed last August's eclipse over the US?

Planets, Comets and Asteroids

Our Solar System is full of amazing objects, from passing comets to the mesmerising rings of Saturn or the beautiful phases of Venus. Which of our cosmic neighbours inspires you?



Our Moon

Simple to begin with but tricky to master, lunar imaging offers boundless variation. A fantastic target for beginners as well as more experienced astrophotographers, and there are many ways to image it, whether up close or as a wider shot of the night sky.

YURI ZVEZDNY, MIKKEL BEITER, HAITONG YU, ARTEM MIRONOV, OLEG BRYZGALOV, ALEXANDRA HART, ROGER HUTCHINSON, LÁSZLÓ FRANCSICS

SPECIAL PRIZES

The Sir Patrick Moore Prize for Best Newcomer

Sir Patrick was famed for introducing astronomy to new generations, so it's fitting that this prize is awarded in his name. It is open to those who have only been astro imaging for a year or less.

Robotic Scope

Thanks to the internet, these days anyone can get time on some of the world's most impressive telescopes from the comfort of their home and take amazing images of the night sky. If you've mastered capturing the cosmos via robotic scopes, enter your best images into this category.

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

CELEBRATING 10 YEARS

A decade of showcasing the best astrophotos

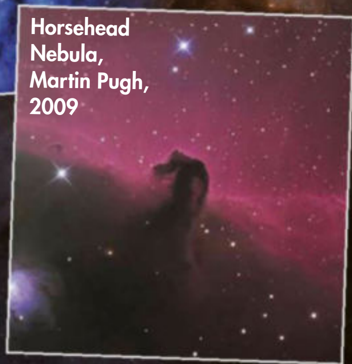
As the Insight Astronomy Photographer of the Year competition opens its 10th chapter, it celebrates a remarkable decade of success championing the very best in astrophotography.

During its inaugural year in 2009, the competition received around 500 entries. Martin Pugh from Dudley was announced as the first overall winner with his image of the Horsehead Nebula, taking home a top prize of £1,000.

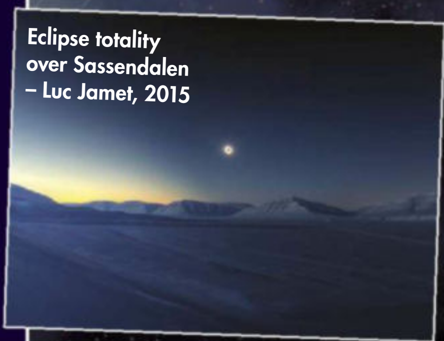
The competition grew steadily in the following years, and in 2015 it gained a new title sponsor in Insight Investment, a leading global asset manager.

Fast forward to 2017, and IAPY received almost 4,000 entries from photographers in 91 countries across the globe. A prize of £10,000 was awarded to the overall winner, Russian photographer Artem Mironov, and his image of the Rho Ophiuchi Cloud Complex.

Rho Ophiuchi, Artem Mironov, 2017



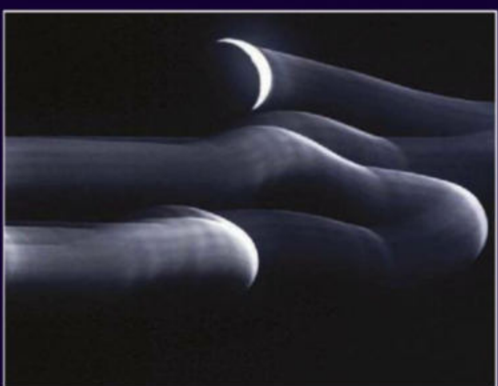
Horsehead Nebula, Martin Pugh, 2009



Eclipse totality over Sassendalen – Luc Jamet, 2015

Since 2009, the competition has encouraged an interdisciplinary approach to astrophotography and this has been reflected in the judges. As well as well-known astronomers and astro imagers such as Sir Patrick Moore and Damian Peach, Turner prize-winning photographers, art curators and picture editors have brought an original view to the judging panel over the years.

To celebrate the 10th competition, the winners will be exhibited in a new, larger, dedicated gallery space at the National Maritime Museum, and the opening of the 10th exhibition is sure to be celebrated in style. Who knows? Maybe we'll see you at this year's awards ceremony.



INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR – YOUNG COMPETITION

IAPY also celebrates the next generation of astro imagers through the Young Astronomy Photographer of the Year competition. It's open to all aged 15 years and under, with a £1,500 prize for the winner, £500 for the runner-up and £250 for each of the three highly commended images.

JASON GREEN, GERALD RHEMANN, LUC JAMET, MARTIN PUGH, ARTEM MIRONOV, OLIVIA WILLIAMSON, KIMBERLY OCHOA

THE VIRTUAL UNIVERSE

ABOUT THE WRITER
Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD from Cardiff University

Elizabeth Pearson looks into how virtual reality can transport you from your living room to the surface of Mars and beyond

Have you ever wanted to look out of the Cupola on the International Space Station and watch the world passing below you? Have you wished you could walk on the surface of Mars, sit at the controls during the Apollo 11 mission, or fly over the Milky Way? Now, thanks to the increasingly sophisticated world of virtual reality, or VR, you can.

To run the most advanced VR programs at home you will need a VR headset, such as the HTC Vive or Oculus Rift, as well as a computer running Windows with enough power to run the software that controls them (unfortunately, most VR games do not support Macs). But if you don't have the hardware, don't worry. With the use of a cardboard viewer that can be bought for a few pounds, any smartphone with a gyroscope can be transformed into a VR headset, capable of running several programs. Over the following pages, we'll take a look at some of the best apps and games that can help you explore the Universe. ▸

ISTOCK X 7

PLANETARIUMS & STAR CHARTS

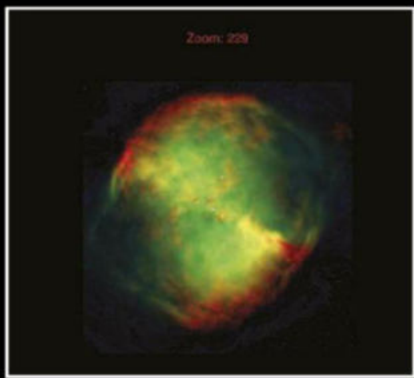
Turn your smartphone into your personal planetarium

Universe2Go Android; Free • iTunes; Free

Using a special viewer with a glass front (£59.90), this app projects what's shown on the phone's screen onto your view of the night sky, allowing you to identify real stars simply by looking at them. You can use overlaid constellation lines and names to make the patterns more familiar, or turn them off for an unimpeded view.

The system uses a sequence of head tilts to navigate around the menu system. This includes the option to choose between modes to get audio descriptions from a cultural, historical or scientific perspective.

It can take some time to get the brightness settings balanced so you can see both overlay and the night sky but, once correct, the app is a great aid in navigating the stars. Not all smartphones have the in-built gyro required for the app to work properly, so check before you buy.
https://universe2go.com



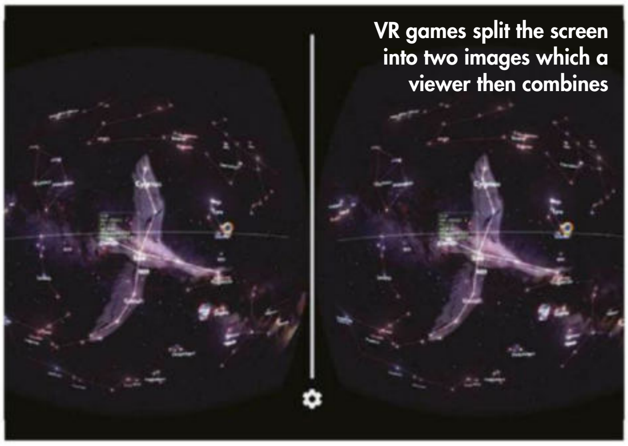
▲ Universe2Go shows art and astrophotos

Star Chart VR

Android; £2.99 • **iTunes**; £0.99 • **Oculus**; £3.99 • **Vive**; £6.99

This app straddles the line between a star chart and a deep-space explorer. You float above the Solar System, and can swoop from place to place by clicking on planets using the headset's buttons to get a closer look. Then swap to Earth View for a total 360° vista of the night sky. Look at a star to bring up scientific information about it.
www.escapistgames.com/sc.html

Star Chart VR lets you soar around the night sky



VR games split the screen into two images which a viewer then combines

Startracker VR

Android; free
Oculus; £0.79

A beautifully rendered and simple star chart, this app fills the sky with the stars of the 88 constellations and over 100 deep-sky objects, positioned as they would be in the sky above you. Though all the stars are shown with equal brightness, you can bring up an info box with their magnitude by looking at them.
https://sites.google.com/site/pyopyostudioapp

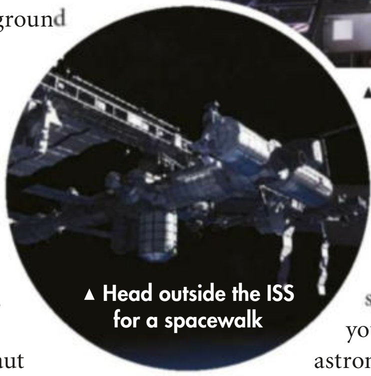
TOURS & SIMULATIONS

Your ticket to unreachable destinations

Mission:ISS

Oculus; Free

▲ Coax in a resupply vehicle



▲ Head outside the ISS for a spacewalk

Mission:ISS allows you to explore a highly realistic model of the International Space Station (ISS), which includes every detail down to the stickers on the walls and the background hiss of the air system.

Inside, you move around the station using handrails and pushing off walls, like a real astronaut. Navigating in all three dimensions is quite disorientating (and can be a little nauseating), but it does recreate the feeling of being an astronaut getting to grips with microgravity. The Explore mode lets you move freely about the station and its modules, including the Cupola, which gives you a glorious view of Earth passing below you. Meanwhile, Mission mode takes you on a tour of the space station, setting you various tasks astronauts regularly perform such as capturing a resupply craft or performing a spacewalk to check for damage.
http://missioniss.magnopus.com

Apollo 11 VR

Vive; £7.50
Oculus; £7.99

Apollo 11 VR is an interactive documentary that lets you join the historic mission by putting you in the place of Buzz Aldrin. During certain segments, such as landing the lunar module, you can choose to take control of the action yourself. The voice-over features archive recordings from mission control.
http://immersivevreducation.com

Titans of space

Android; Free • **Oculus**; £5.99
Vive; £5.59

Take on the role of a Solar System tourist and soar past scale representations of the planets and their moons. Then watch as the action pulls back to show you how our Sun measures up against its stellar cousins, and with the Solar System at large. The premium headset version includes a voice-over for you to enjoy.
http://titansofspacevr.com

Each world has its own fact file

The school bus Mars VR experience was a big hit with the kids

A FIELD TRIP TO MARS

Hoping to inspire the next generation of Martian engineers and astronauts, bus loads of children were transported to the Red Planet

In 2015, groups of schoolchildren boarded what appeared to be an everyday yellow school bus in Washington, DC. But after a few minutes of driving, the windows turned dark and then suddenly, the children were transported to the surface of the Red Planet.

"The windows were actually transparent screens," says Ron Fosner, who was lead developer on the project, called Field Trip to Mars. "From inside a dark school bus they look like a regular window, but then we opaque them and the monitors come on, showing the surface of Mars. It was a stealth installation, so from the outside you couldn't tell that anything was different."

To create the view, the team had built a virtual representation of Mars in a computer, then displayed this on the screens to make it look like they were driving along the Martian surface. Using GPS, accelerometers and velocimeters, they synchronised with the motion of the bus so that when it turned or bounced, the view out of the window did as well.

"We had a Mars rover and a colony that the kids could look at as they were driving past," says Fosner. "Then three quarters of the way through we had a sandstorm. There was 400W surround sound, so the windows on the bus were rattling while the view outside the bus was totally dark with red sand for 10 to 15 seconds.

"We got a lot of compliments about how different it was. A lot of people have experienced VR, but they hadn't seen anybody do a large-scale VR installation like this before. Once the windows switched on they were just screaming out loud, even the adults."
www.fieldtriptomars.com ▸

LOCKHEED-MARTIN

ENTERTAINMENT

VR can be lighthearted as well as educational

Engineers test Microsoft's Hololens on NASA's Weightless Wonder C9 jet

Universe Sandbox 2 Oculus, Vive; $24.99

This physics-based space simulator gives you control over the Universe. The game creates simulations of planetary systems, stars and even galaxies, then gives you free rein to alter them. You can launch planets into new orbits or fire moons into the Earth (pictured), then sit back and watch as the effects of your chaos unfolds around you. The game is in early release, so is still being worked on, and some of the tutorials are currently missing. However, experimenting with what the game can do provides much fun. This particualr VR game includes a desktop version, where you can craft your own detailed planetary systems. You can then load these into the VR version, allowing you to fly through them, hopping from planet to planet to get a better look at your creation. http://universesandbox.com/vr

Take in the view from low-Earth orbit in Home

Home: A VR Spacewalk

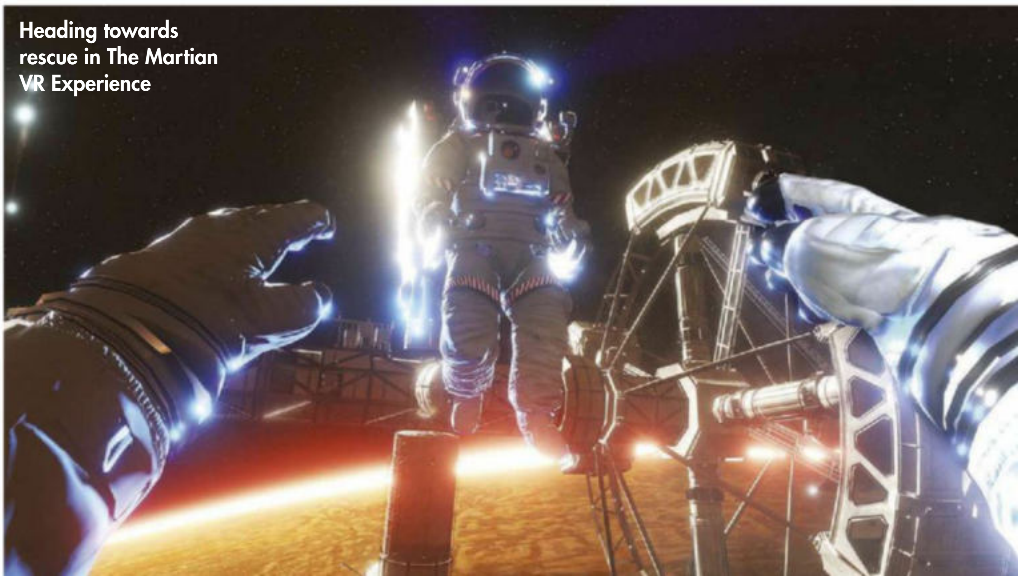
Oculus, Vive; Free

Inspired by Tim Peake's spacewalk in 2016, this game challenges you to travel outside the ISS and inspect a damaged solar array. But a strike by some orbital debris sends you spiralling into space, and you have to get yourself back to safety. What really makes this experience is looking over to see our home planet passing beneath you. **http://rewind.co/portfolio/bbc-home**

The Martian VR Experience

Oculus, Vive; £7.99

Based on the hit movie of Andy Weir's best-selling book, The Martian VR Experience lets you take the role of astronaut Mark Watney, who has been stranded on the Red Planet. You have to do some potato farming, drive a Martian rover, and then fly through space to your rescue. These short sections are cut together with clips from the movie, creating a VR trailer. **www.foxvrexperiences.com**



Heading towards rescue in The Martian VR Experience

SPACE TRAVEL'S VIRTUAL FUTURE

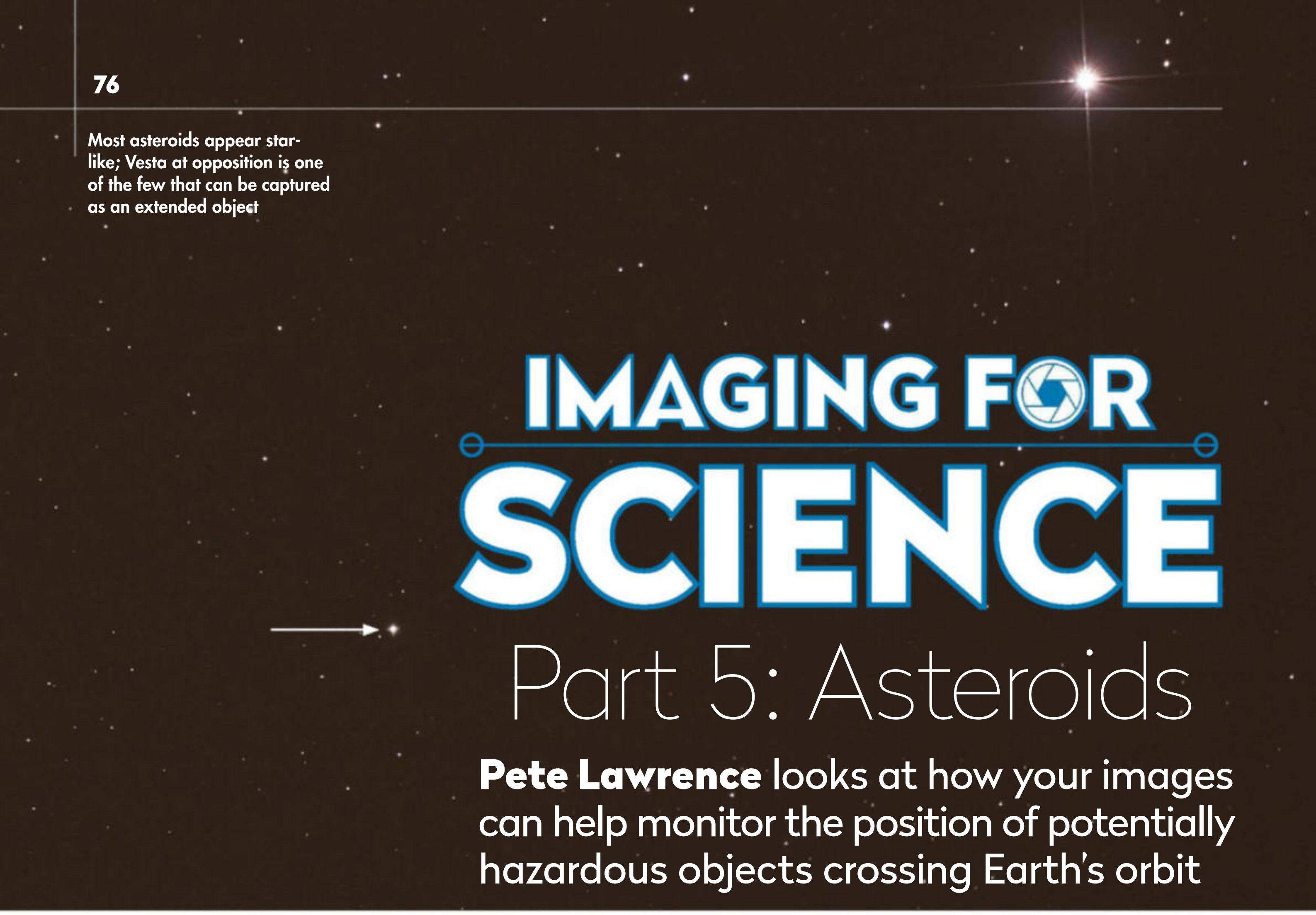
Whether it's on the ground or on the ISS, VR is helping to further space science

When astronaut Tim Peake ventured out into space for the first time, it was not his first ever experience of a spacewalk – Peake had performed the task dozens of times in virtual reality.

Virtual reality has been part of astronaut training for years, but as headsets get cheaper, they can be found in more departments around NASA and ESA. Building components in VR allows engineers to examine and test their work without the need to manufacture expensive prototypes. Meanwhile, planetary geologists are no longer stuck looking at flat images of distant worlds. VR allows them to create mock-ups of the territory they are investigating, which they can then walk around and examine in detail.

The lightweight headsets are heading even further afield, into space itself. In 2015 NASA flew some Microsoft Hololens headsets – which project images over the wearer's view of reality – to the ISS. The aim is to use the technology to train astronauts while in orbit, create helpful overlays to aid in complex procedures, and eventually control robotic helpers on the surfaces of other planets from orbit. Alternatively, they can be used for fun, as Tim Peake and Scott Kelly showed – they used their headsets to play Space Invaders while off duty. S

NASA, 20TH CENTURY FOX INNOVATION LAB



Most asteroids appear star-like; Vesta at opposition is one of the few that can be captured as an extended object

IMAGING FOR SCIENCE

Part 5: Asteroids

Pete Lawrence looks at how your images can help monitor the position of potentially hazardous objects crossing Earth's orbit

ABOUT THE WRITER
Pete Lawrence is an expert astronomer and astrophotographer who holds a particular interest in digital imaging

Asteroids or minor planets are small Solar System bodies that are visible because they reflect sunlight. The larger members of this group have dimensions measured in hundreds of kilometres, but asteroids can be as small as 1m along their largest axis. Most asteroids are located in what's known as the main belt, a huge repository for such objects located between the orbits of Mars and Jupiter. In all but very rare circumstances, asteroids appear star-like through amateur scopes. Visually, they can be measured in terms of their brightness, position and occasional apparent interactions with other objects.

The sheer number of asteroids in orbit around the Sun means that occasionally we get to see one occult a distant star. Asteroid occultations provide an important way to determine the shape profile of these rocky bodies.

Accurate date and time recording is vital when observing asteroids, as it is this information which ultimately is used to refine the object's orbit and position.

Hardware & Software

HARDWARE

Small and large telescopes
DSLR and CCD cameras

SOFTWARE

Astrometrica (www.astrometrica.at; shareware; €25)
Cartes du Ciel (https://sourceforge.net/projects/skychart; free)
Occult (www.lunar-occultations.com/iota/occult4.htm; free)
LiMovie (http://astro-limovie.info/limovie/limovie_en.html; free)
OccultWatcher (www.occultwatcher.net; free)
GIMP (www.gimp.org; free)

Submit your pics for science

"When the Asteroids and Remote Planets Section of the BAA was founded during the early 1980s, relatively few 'small Solar System bodies' had been discovered and observations were only possible either visually or using photographic methods," says Section director Richard Miles (pictured).

"Since then a revolution has taken place, thanks to the development of extremely effective CCD cameras. To date more than 750,000 individual 'minor planets' have been discovered, of which almost 18,000 are near-Earth objects (NEOs). We now know these objects have very varied origins.

"So the aim of the Section is to study particularly interesting objects, whether as part of the flurry of activity when a new NEO passes close by Earth, or through more systematic studies of the various types of object known via organised observing campaigns where team efforts from observers around the world can achieve much more than would be possible by someone working alone.

"For these studies, we employ the techniques of astrometry and photometry (positional and brightness measurement) and stellar occultations (when an object is predicted to pass in front of star) so that we are able to probe the nature and orbital characteristics of asteroids. Given that the Solar System houses a 'celestial zoo' of strange objects, much remains to be done."

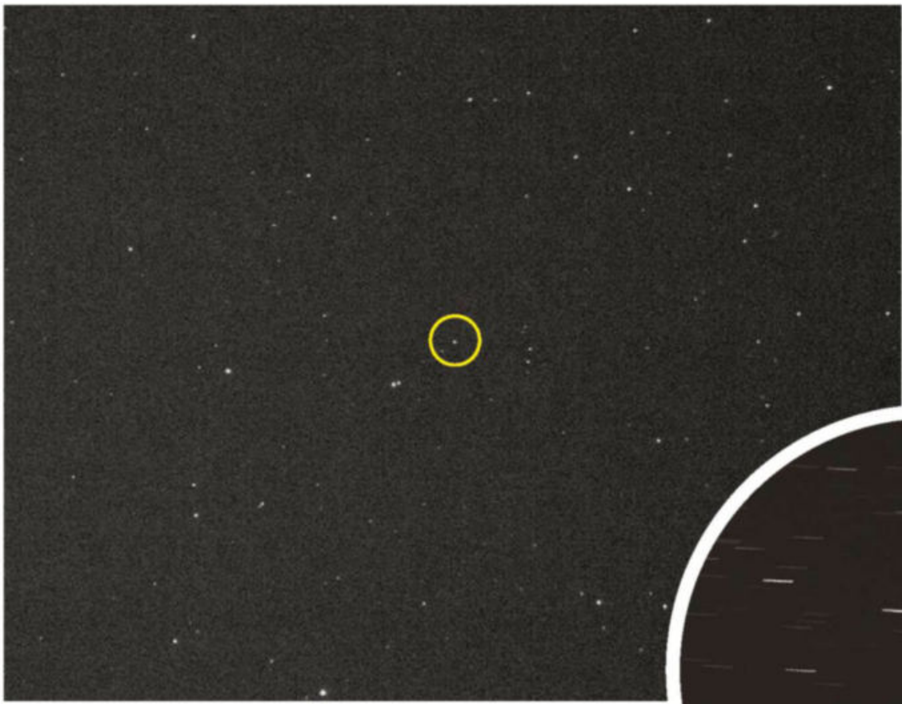
Find out more at: www.britastro.org/section_front/8

PETE LAWRENCE X 4

PROJECT 1

Asteroid photography

The low-down on how to take scientifically useful images of minor planets



▲ A five-second shot of asteroid 2014 JO25 records it as a star-like dot

Asteroids look just like stars when viewed through a telescope. It's only when their positions have been noted or photographed over an extended period – normally days – that their motion and true nature is revealed. Most asteroids appear to move slowly against the background stars but those that venture close to Earth may have enough apparent speed to appear to move in real time when viewed through a telescope or binoculars.

Tracking the asteroid in an image will cause the stars to trail

Bodies that have orbits bringing them close to Earth are known as near-Earth objects (NEOs) of which near-Earth asteroids (NEAs) are a subset. NEOs larger than 140m that cross Earth's orbit are classed as potentially hazardous objects (PHOs) and again, asteroids form a subset known as potentially hazardous asteroids (PHAs). To date, all known PHOs are PHAs.

Scientific asteroid images for astrometry and photometry need to record the body as a sharp dot without trailing. For slow-moving asteroids this may not be an issue, but fast movers require short exposures or setups that track the asteroid itself. This is especially useful for the high-cadence photometry necessary to determine the light curve, and hence spin-rate, of an asteroid.

For more general appeal, in outreach material for example, a fast-moving asteroid provides a convenient way to produce a trail that would otherwise take many extended exposures to capture. In this instance, a correctly polar aligned telescope tracking at the sidereal rate or, better still, autoguided on the stars, will produce a sharp star field with the asteroid as a light trail. A similar effect can be created by aligning shorter exposures on the stars, and stacking them with the brighter elements set to show through.

Many asteroids are within range of a basic telescope and DSLR setup. For scientifically calibrated work, CCD cameras, (preferably with specialist filters) are recommended. By using planetary imaging techniques, larger telescopes may even be able to capture larger asteroids as extended discs during favourable oppositions, rather than the usual star-like dot. ▸

Asteroid 2004 BL86, imaged as a 60-second exposure; the 300m space rock was moving fast enough to present a 2.4-arcminute streak

PROJECT 2

Asteroid astrometry

Use software to help you plot the exact position of small space rocks

Measuring the position of an asteroid is an important step in determining and refining its orbit. This is especially true for asteroids on eccentric orbits, which have the capacity to pass close to Earth. Smaller bodies returning to the inner Solar System may have been gravitationally perturbed, leading to changes in the previously established orbit, and these need to be monitored.

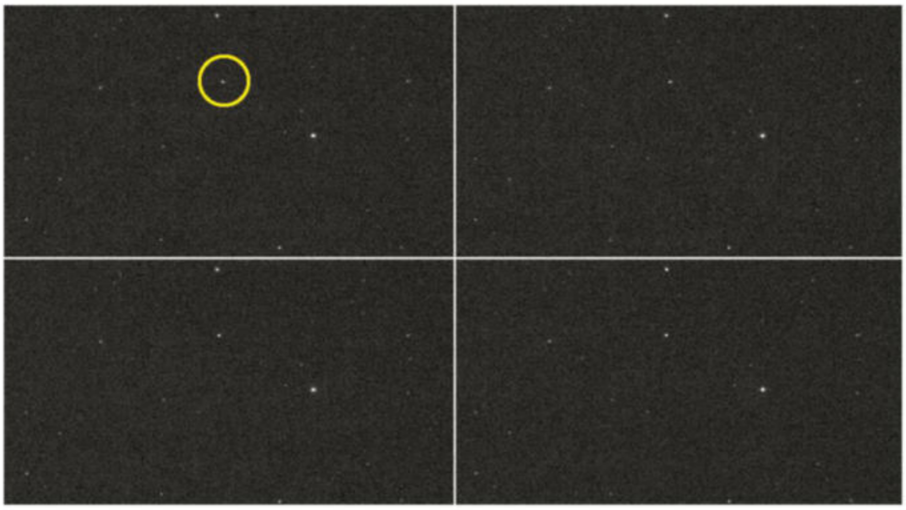
The astrometry of asteroids is similar to comet astrometry (which we covered in Imaging for Science last month), with the exception that asteroids are somewhat easier to measure, appearing as singular dots of light without the complexity that accompanies the expansive head of a comet.

It is recommended that serious astrometric measurements follow the guidelines set out by the International Astronomical Union's Minor Planet Center (MPC), available online at **www.minorplanetcenter.net/iau/info/Astrometry.html**.

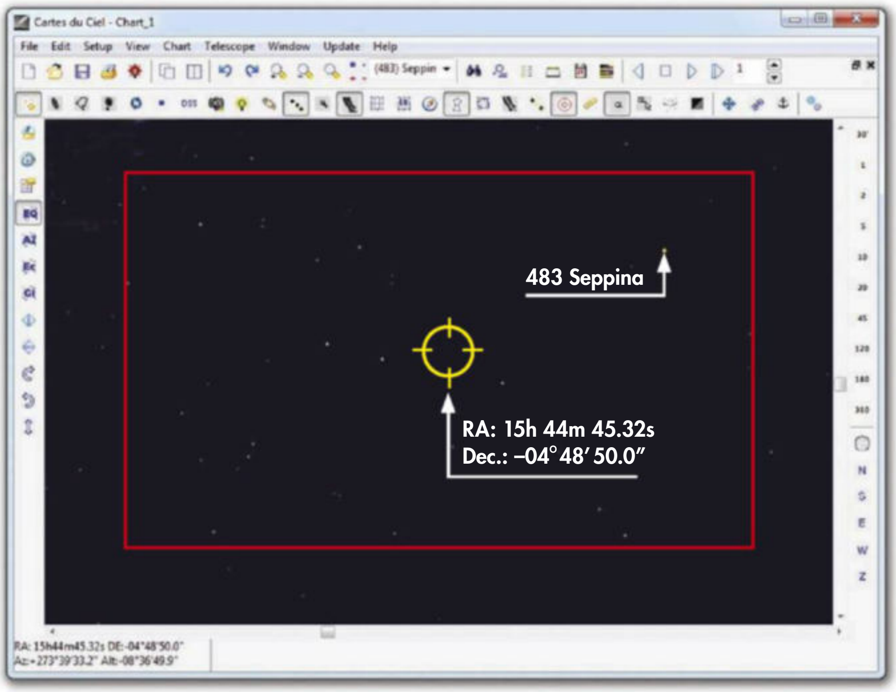
The basic workflow for the astrometric measurement of an asteroid is quite straightforward. First you need to obtain a set of images that include the object you intend to measure. Then you'll need some software assistance to measure the position accurately; the shareware Astrometrica is highly recommended.

Astrometrica allows you to 'blink' your images, which should reveal the asteroid moving against the static star field. The software will need to identify the star field in the images in order to determine the asteroid's position. You can help here by manually identifying the star field and supplying Astrometrica with the correct RA and dec. coordinates for the centre of the imaging frame. Once entered, the program attempts to match the star field.

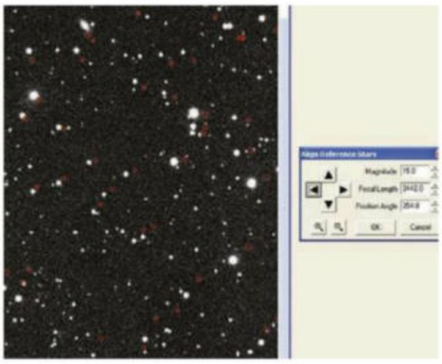
If it doesn't quite get things right, you can adjust the alignment manually. Astrometrica's star template can be adjusted for scale with a focal length used setting, for rotation with a position angle setting and positionally with an onscreen arrow key pad. Once the alignment has been set, clicking on the object will generate an MPC compatible log file of positional data which can then be submitted according to the submission guidelines.



▲ Blinking between images will reveal motion, though the difference can be almost imperceptible



▲ Using planetarium software such as Cartes du Ciel, you can determine the approximate centre of the image frame (red), which you can feed into Astrometrica to assist in star field identification



▲ Once the approximate centre of the image has been determined, a catalogue match in Astrometrica can be achieved by tweaking the position of the catalogue stars (red circles) so they overlay the stars in the image

PETE LAWRENCE X 6, IOTA X 1

PROJECT 3

Asteroid photometry

Accurately plotting of the brightness and shape of distant asteroids is a team effort

Occasionally an asteroid will pass in front of a star, dimming the stars's light as it goes. There are numerous programs available to predict such events as well as websites, such as Euraster, which presents results without you having to having to calculate them yourself.

A typical asteroid occultation path will be a narrow track and may require you to travel to a specific location in order to view and record the event. This adds additional complexity in that it requires the use of a portable observing and recording setup and a means to accurately calculate your location and altitude. The modern way to do this is with some form of GPS recorder.

One of the hardest parts of observing asteroid occultations is to locate the star that is going to be occulted. This can be done using a Go-To system, but you often need to use very accurate star charts to augment the process, especially when the star to be occulted is very faint.

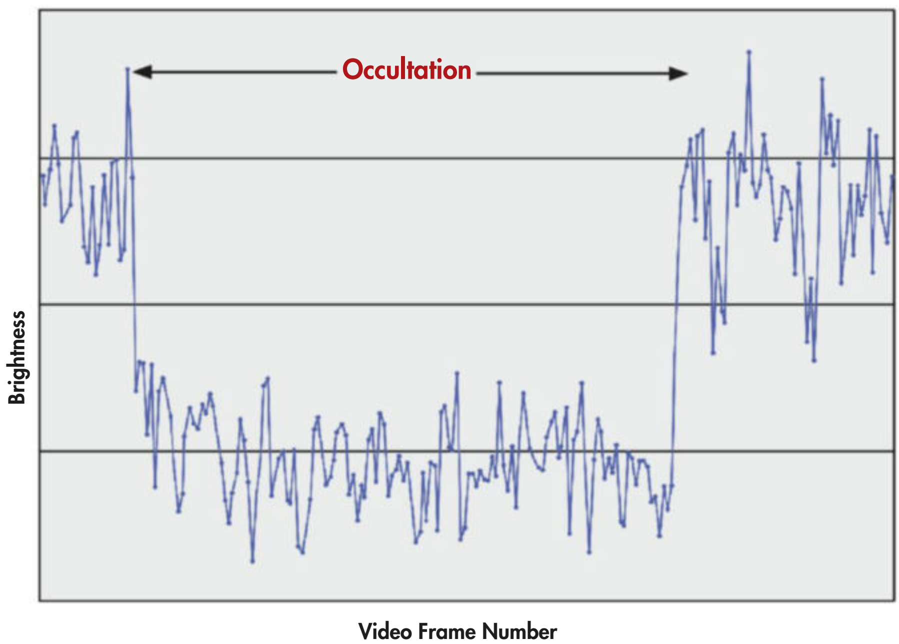
A common way to record asteroid occultations is with a low light video camera. The resulting video, normally recorded in the AVI format, can then be analysed by specialist programs such as LiMovie or Tangra, which are both available for free.

A successful occultation should produce a light graph for the star that shows it dim as the asteroid passes in front of it and brighten as the asteroid moves out of the way. Accurate timing of the star's dimming will produce a line profile across the asteroid. Interesting though this is, such profiles really become useful when multiple observers record and communicate these events. With multiple profiles recorded, it's then possible to produce a more complete profile of the asteroid.

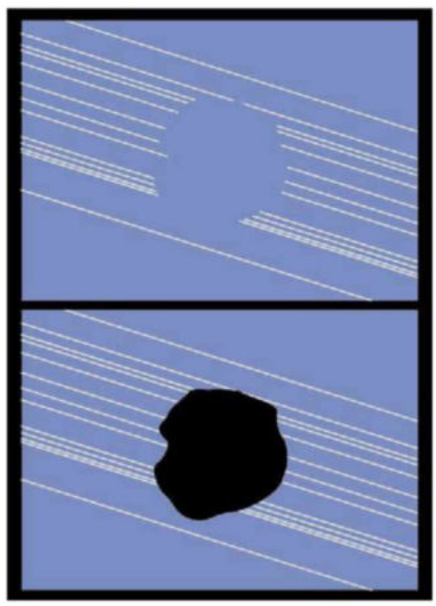
▲ Freeware program Occult can be used to generate accurate asteroid occultation predictions and identify where on Earth you need to be to witness each event

▲ IOTA's VTI can add UTC time stamps to your frames

Obviously for this to be of any worth, a highly accurate time signal needs to be used. A device such as the International Occultation Timing Association's video time inserter (IOTA-VTI; **https://occultations.org**) is an ideal way to do this as it has the capability to insert coordinated Universal Time (UTC) on every frame of a recorded video signal. Ⓢ



▲ After analysis with a program such as LiMovie, an occultation video can be used to identify the frames that represent disappearance and reappearance of the distant star. If the frames are accurately time calibrated, the moment of the occultation can be determined



▲ The benefit of collaboration: a series of occultation timelines from a group of observers (top) can be used to produce a partial reconstruction of an asteroid's profile (bottom)

SKILLS

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Brush up on your astronomy prowess with our team of experts

The Guide

With **Steve Richards**

The importance of eyepieces

Why these small components matter, and the best ones to start stargazing with

▲ **The three most common designs of eyepiece you'll come across as an observer: an orthoscopic (left), a Plössl (middle) and a wide angle (right)**

PAUL WHITFIELD, THE SECRET STUDIO X 3

When starting out in astronomy, it is quite natural to think mainly in terms of the telescope that you want, with hardly a thought given to the eyepieces that go with it. Indeed, many telescopes come with one or more eyepieces as part of a kit.

However, the telescope is only part of the observing equation. Telescopes work by collecting light and then bending the rays to bring them to focus at a point known as the focal plane, but it is the eyepiece that brings this valuable light to your eye – so its quality and suitability for the purpose are just as important as the scope itself.

Your choice of eyepiece will determine the magnification and the size of the field of view that your telescope will deliver. Eyepieces and telescopes are denoted by their focal lengths. Together, the two focal lengths produce a magnification, calculated as the telescope's focal length *divided by* the eyepiece's focal length. The take home message from this is that the shorter the focal length of the eyepiece, the higher the magnification you will have.

But it's important to realise that good observing is not all about magnification; in fact, too high a magnification can spoil the view. Different celestial objects are best seen at different magnifications, which is

BARLOW LENSES

The eyepiece companions that modify magnification

No discussion about eyepieces would be complete without mentioning Barlow lenses. Although a Barlow is not an eyepiece in its own right, it is frequently used with in conjunction with an eyepiece to increase your magnification.

A Barlow lens is a tube containing lens elements that diverge the light passing through them. If a Barlow lens is inserted into the light path of a telescope, the effective focal length of the telescope is increased.

As the magnification of an observing setup depends on the focal lengths of both telescope and eyepiece, an increase in the effective focal length of the telescope results in an increase in magnification. Most Barlows increase magnification by two times.

why most observers have a range of different eyepieces. Typically, a collection of four – 6mm, 10mm, 15mm and 25mm – will cover most observing requirements.

Another important attribute is the eyepiece's apparent field of view (AFOV), which will normally be marked on the body along with its focal length. Values range from 45° to over 100°, but the eyepiece's true field of view with a given telescope can be worked out with another simple calculation: apparent field of view *divided by* the magnification.

Also important is the build quality of your eyepiece and particularly its lens elements; quite exotic glass is a prerequisite. However, as eyepieces commonly have four or more individual lens elements within them, non-reflective coatings are also vital, to cut down reflections between the lens surfaces that would otherwise reduce the contrast and spoil the view. The quality of these non-reflective coatings is an important factor in the choice of eyepieces.

Sometimes, additional steps are also taken to increase contrast – such as ensuring that the inside of the eyepiece body is a very matt black. Some manufacturers also blacken the edges of individual lens elements to further reduce reflections.

Three core designs

There are various types of eyepiece available, the three most popular designs being Plössl, orthoscopic and wide angle.

Plössls often ship with new telescopes, though these 'bundled' eyepieces can vary greatly in quality. They commonly have an AFOV of 52° and are typically available in focal lengths from 6mm to 32mm. Plössls of good quality are excellent all-round eyepieces, although the ones with shorter focal lengths do suffer from short eye relief, and this can sometimes make observing a little uncomfortable. Plössls generally have 1.25-inch barrels, but some 2-inch variants are available. These have the advantage of a longer eye relief and the ability to accommodate longer focal lengths.

Orthoscopic eyepieces are renowned for their excellent distortion and aberration-free views, although they typically have a narrower AFOV of between 40° and 45°. They excel at lunar and planetary observations, where a wide field of view is of lesser importance than image purity. Almost all orthoscopics have 1.25-inch barrels.

Wide-angle eyepieces are available in a range of AFOVs from 68° to as wide as 120°. These eyepieces help to give the illusion of 'floating' in space rather than looking through a porthole, which can be the feeling you get with narrow AFOV eyepieces. This type of eyepiece is very well suited to scrutinising star clusters and larger deep-sky objects. Wide-angle eyepieces require 2-inch diameter barrels.

There are, of course other eyepiece designs, and these include Kellners, modified acromats, Huygens and Konigs. But they are not as popular as they don't match the quality of the other types. S

STEVE RICHARDS is *BBC Sky at Night Magazine*'s Scope Doctor

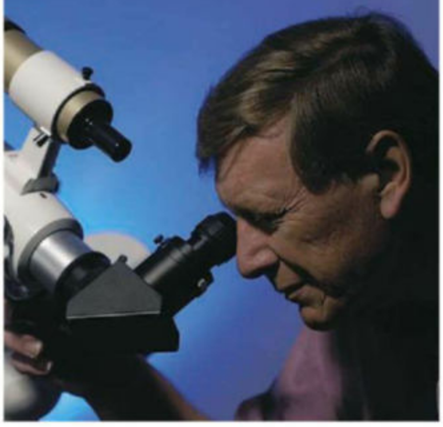
JARGON BUSTER

THREE MORE TERMS YOU SHOULD KNOW

EXIT PUPIL
Light emerging from an eyepiece produces a small circular image known as the exit pupil, the diameter of which is calculated by dividing the eyepiece's focal length by the telescope's focal ratio.

EYE RELIEF
Eye relief is the fixed distance from the curved surface of the outermost lens of an eyepiece to the point at which the exit pupil is formed. Longer eye relief gives more comfortable observing.

POWER
Power is simply another name for magnification and it indicates how many times bigger the object will appear through the eyepiece in comparison with the naked eye.



How to...

Build a stomp rocket launcher

With
Jo Richardson

Shoot for the Moon with this fun STEM activity

The rocket ready for lift off: stamp hard on the bottle and your spacecraft will go flying

TOOLS AND MATERIALS

MATERIALS
2L plastic bottle, six lengths of 0.5-inch-diameter PVC pipe (three 12 inches long and three 6 inches long), two 0.5-inch PVC T connectors, one 0.5-inch straight PVC connector, two 0.5-inch PVC blanking end caps, A4 paper

TOOLS
Duct tape, sticky tape, ruler, protractor, marker pen, scissors

Working within space outreach education, it is almost impossible to find anyone who is not fascinated by real rockets – whether that is because of their immense power, their sheer noise or simply the fact that they have opened up our ability to explore the Solar System and land astronauts on the Moon.

Firing rockets in workshops and at events captures an audience's imagination like nothing else. This is especially true for children, who not only find great delight in designing and making their rockets, but also by having the 'responsibility' for blasting them high into the sky, be it by air, water or fizzy tablet power! As well as being great fun, it's also a way of encouraging children to take an interest in STEM subjects – science, technology, engineering and maths – so that they can become the engineers, technicians and astronomers of the future.

The stomp rocket launcher (and rocket) we're going to show you how to make this month is a great way to do just that. It not only teaches mathematical abilities in measuring out materials but, with the development of a subsequent rocket, it illustrates the importance of good technical design and highlights the scientific ideas behind forces and motion.

Ready to rock(et)

All of the materials are relatively inexpensive and can be purchased from the plumbing section of a DIY store. If you are making this project with kids, it is a good idea to have the PVC pipes pre-cut to length: that way they can put

▲ You can decorate your rocket however you like – though stars are an appropriate choice

the launcher together themselves, with little or no help beyond the step-by-step guide given here.

The rocket itself is very simple to make and offers the opportunity to experiment with different designs and adaptations. Using plain paper for the rocket allows it to be decorated with pens, crayons, paints, glitter and stickers. Or, alternatively, it can be left white for a more 'authentic' look.

Here is our guide for the perfect rocket: using a spare piece of pipe both as a support and as a guide, roll a sheet of A4 paper and tape the seam carefully – this ensures the paper rocket is the right diameter for the plastic pipe that serves as its 'launch pad'. Do make sure there is still some movement between the pipe and the paper, otherwise it will not fire successfully when mounted. This is also the point at which you can decide on the livery and add it to the rocket.

To make the nose cone, draw a semi-circle on a piece of paper using a protractor and cut out. Roll it tightly into a cone that matches the diameter of the pipe, and tape the seam. Attach to the top of the 'rocket fuselage' using sticky tape, ensuring there are no gaps that air can seep through. You can always make a simplified rocket without a nose cone by just pinching the top of the rocket tube together and securing that with tape, again ensuring that there are no gaps.

Fins are traditionally triangular shaped, but you could try experimenting with different shapes to see if they affect the rocket's flight. Cut them out of the paper, fold as appropriate and affix to the bottom of your rocket using sticky tape. Once complete, the rocket is ready to be fired from the launcher time and time again. S

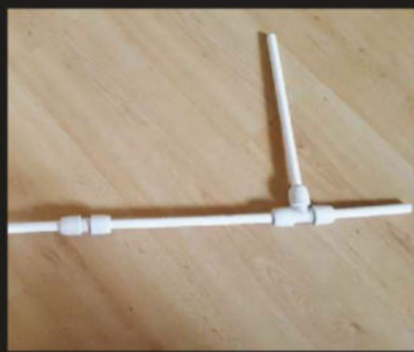
JO RICHARDSON runs the Space Detectives astronomy workshops and is an ESERO-UK space ambassador

STEP BY STEP

STEP 1
Draw a bullseye onto the middle of the plastic bottle. This gives you somewhere to aim for with your foot when you come to stamp on the bottle, which also helps with reinflation – if the bottle gets squashed near the bottom it may not pop back into shape.

STEP 2
Insert one of the 12-inch PVC pipes into the neck of the bottle and secure it using duct tape. Ensure that you circle the bottle several times with the tape and keep the tension as you do so to ensure a tight seal. You don't want any air to be able to escape.

STEP 3
Pick up the straight connector and push the free end of the PVC pipe into one end. Then push another 12-inch PVC pipe into the other side of the connector. Ensure a tight seal with no gaps using duct tape as in Step 2.



STEP 4
Take a T connector and push the free end of the last pipe into it. Take your third 12-inch length of PVC pipe and insert into the connector at a right angle to the last. Now push a 6-inch PVC pipe into the free end of the connector.

STEP 5
Attach the final T connector as shown and parallel to the floor. Push your remaining two 6-inch lengths of PVC pipe into it to stabilise the launcher, adding an end cap to the free end of each. Check the seals along the entire launcher.

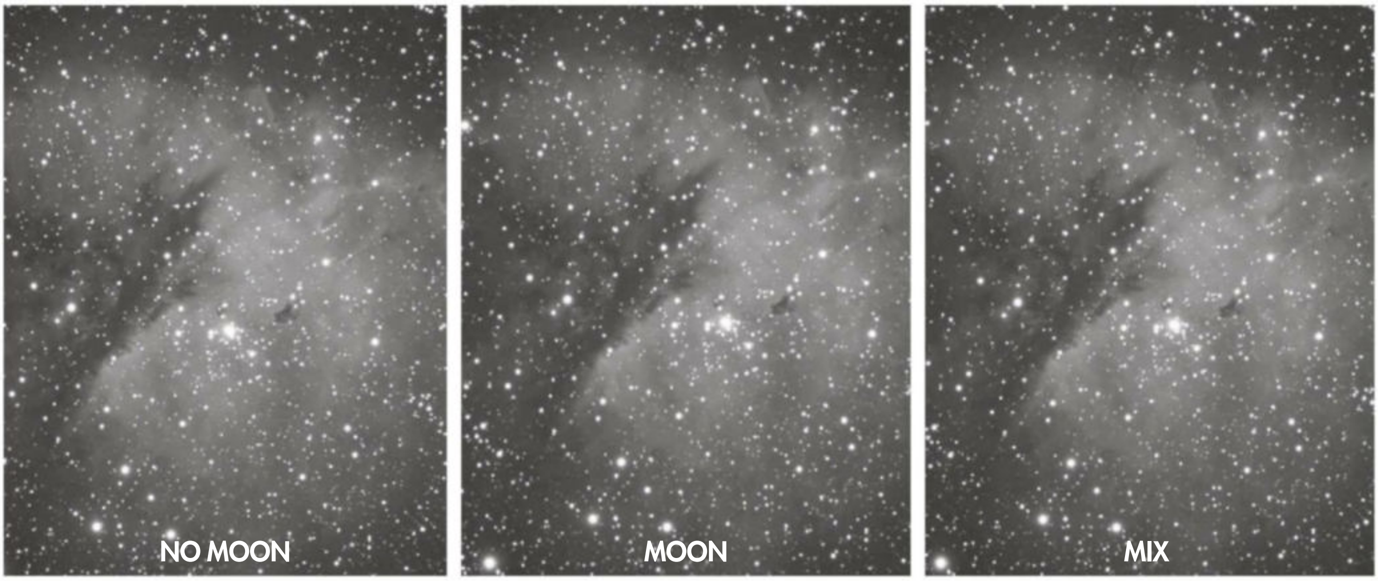
STEP 6
Your launcher is now complete and it should be free standing and portable. You are now 'go for launch'! All that remains is for you to place the rocket onto the launcher in a clear area and see how far you can send it skywards.

Image PROCESSING

With
Sara Wager

Making the best of bad images

Is it a waste of time recording image data in poor conditions? Not necessarily...



▲ Three glimpses of the Pacman Nebula: the moonless data is clearly better than the Moon-affected set, but the quality of the mixed data is a surprise

This month we are looking at how you can work with astronomical images that, under ordinary circumstances, would not get used or taken at all – such as when there is high haze or moonlight, where the higher background brightness can drown out faint details. When your imaging opportunities are limited, less than ideal data may ultimately be the only way to gather enough to process.

To explore whether data taken under poor conditions is worth using, we took images under the harshest combined conditions for imaging: moonlight and an added luminance filter. We recorded data of the Pacman Nebula in Cassiopeia over two nights, taking some images affected by lunar glare and some images without any glare on each evening. That way the conditions for the data were as similar as possible.

On the nights in question the Moon was 75 per cent and 66 per cent illuminated. The equipment used was a 6-inch refractor, a camera with a Sony ICX814 sensor, and a Hutech IDAS light pollution filter that we routinely use to gather luminance data. Each dataset consisted of 27 10-minute exposures and three data sets were used. Each was calibrated using a bias, flat and bad pixel map in Astro Pixel Processor (**www.astropixelprocessor.com**; free trial) with default settings except Winsor Sigma Clip being set to 'In filter' (**Integrate** > **Outlier Rejection** > **Winsor Sigma Clip**) and Kappa Sigma Clip being set to greater than two (**Integrate** > **Outlier Rejection** > **Kappa Sigma Clip**).

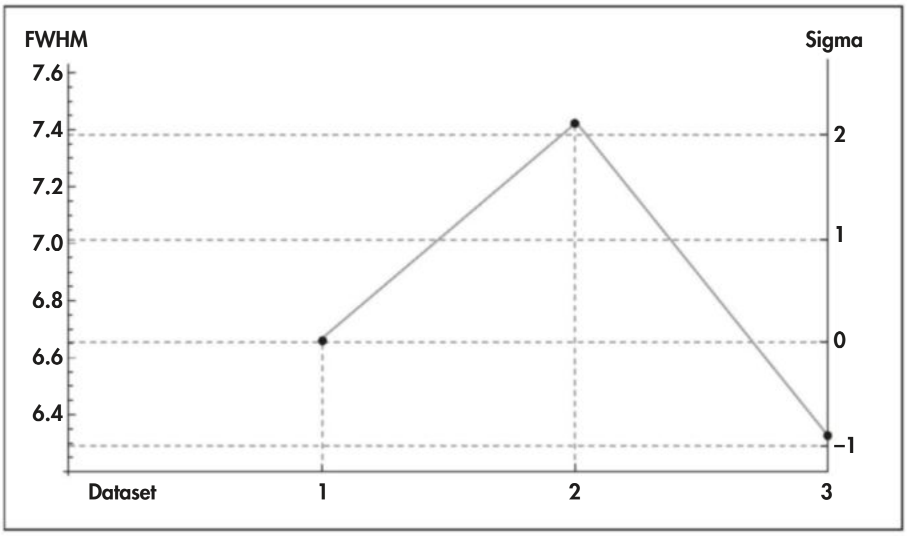
Equal processing

We needed to make sure that the data was all treated equally, so we opened it in PixInsight to complete equal crops (**Process** > **Geometry** > **Dynamic Crop**), equal background equalisation (**Process** > **Background Modelization** > **Dynamic Background Extraction**), and equal stretches (**Process** > **Intensity Transformations** > **Screen Transfer Function** > **Auto Stretch**). At the end, we had three datasets: the first 27 processed 10-minute exposures of moonless data; the second 27 processed 10-minute exposures of Moon-affected data; and the third a mixed set of the two, 14 of moonless data and 13 of Moon-affected data.

It's interesting to see that there are small, subtle differences between the datasets, as shown in the images above. In the Moon-affected data there is slightly more visual noise but a little less contrast, leading to a flatter looking image, but this can be dealt with in processing. The moonless data has a slightly darker background and appears more balanced. When looking at the crop of the datasets, the stars appear to be slightly smaller in the moonless images; something we confirmed using the Subframe Selector script in Pixinsight (**Script** > **Batch Processor** > **SubFrame Selector**).

In the graph on the next page, dataset 1 is the mixed data, 2 Moon-affected data and 3 moonless data – you can see that the

ALL PICTURES: SARA WAGER



▲ **Mixed (1), Moon-affected (2) and moonless (3) data plotted against sigma and FWHM, showing that the stars are sharper and smaller when there is no lunar interference**

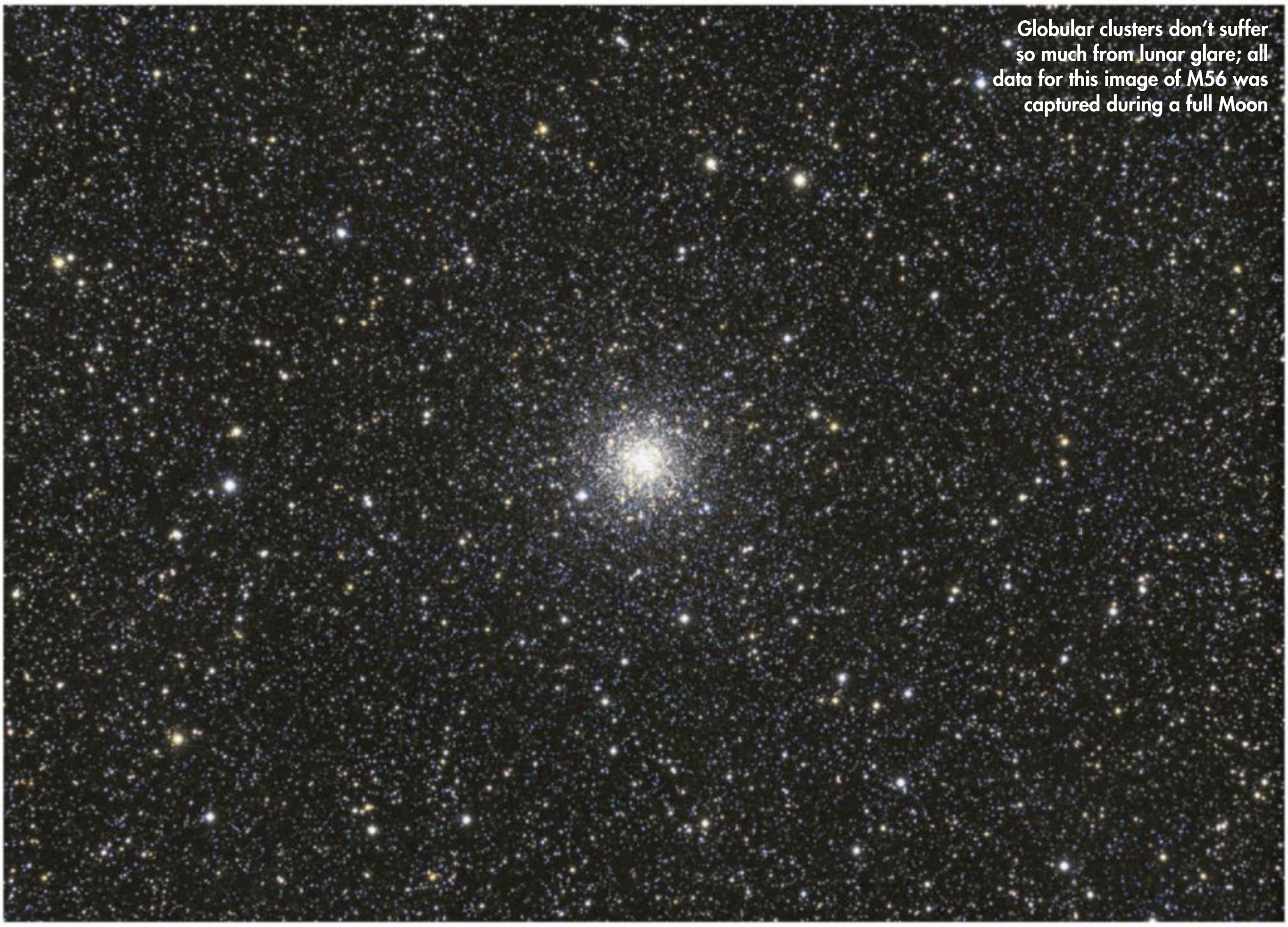
FWHM (full width, half maximum) figure, a measure of focus and star size, is smallest in the moonless data. This is because, despite the sky conditions being the same across the two types of data, the moonlight has a negative effect on overall guiding, leading to bigger stars and potential loss in sharpness. The interesting option is the mixed data set consisting of 14 moonless and 13 Moon-affected exposures. The difference between this dataset and that of the moonless data is negligible; from this, it seems that it is worth keeping all of your data and combining it in equal measure.

There are some caveats to this experiment. The data was not collected when the Moon was full, but there are people who will not collect any broadband data (LRGB) when the Moon is about at all. Perhaps 'some' Moon, with a carefully selected target, need not be quite the data killer that we expect when combined with good data.

The best approach when the Moon is in the night sky is to use a monochrome camera and a hydrogen-alpha filter. The narrower the bandwidth (3nm compared to 7.5nm, for example), the better it will combat moonlight. Bright nebulae tend to have lots of hydrogen-alpha signal in them, whereas galaxies and reflection nebulae contain almost none. As a result, we wouldn't bother trying to collect hydrogen-alpha data on such targets.

Globular clusters, on the other hand, can be imaged in LRGB even when the Moon is full for very satisfactory results. All 20 hours of data in this image of M56 was acquired throughout a full Moon period. There's no detrimental lunar influence on the image. Ⓢ

SARA WAGER is an amateur astronomer who loves imaging nebulae in narrowband



Globular clusters don't suffer so much from lunar glare; all data for this image of M56 was captured during a full Moon

Scope DOCTOR

With Steve Richards

Our equipment specialist cures your optical ailments and technical maladies

I have a Celestron NexStar Evolution 9.25 with built in Wi-Fi. Is it possible to control the scope from my laptop along with my focuser and ZWO camera? Also, can I trigger my StarSense AutoAlign wirelessly?

BOB GOODENOUGH

Although NexStar Evolution mounts have built in Wi-Fi, access to this is currently limited to iOS and Android devices running either SkyPortal or SkySafari apps. However, you mention that you are currently connecting your laptop to a focuser and ZWO camera attached to your telescope. There is no reason why you shouldn't expand this connectivity to encompass full mount control by connecting your laptop directly to the Celestron NexStar hand controller.

Hand controllers manufactured before April 2016 had an RS232 serial port built in but later models have been replaced with a USB connection. If your hand controller has an RS232 connection but your laptop doesn't (which is very likely) then a suitable adaptor like Celestron part number 18775 would allow you to connect the two and control the mount using a wide range of PC-based software, such as planetarium programs.

If your hand controller is the newer type with a USB connector, this is in fact a USB-to-RS232 connection built into the hand controller. When you connect your laptop to the hand controller using a USB cable, you will need to assign a COM port number to the hand controller as though your connection was a normal RS232 serial connection.

I appreciate that this doesn't make use of the built in Wi-Fi and it doesn't allow wireless alignment but it does give you full control via your laptop, which the Wi-Fi connection will not allow.

► You'll need to check the type of port on your Celestron scope's hand controller

WWW.CELESTRON.COM, SKY-WATCHER.COM

I have a Sky-Watcher Skyliner 250PX FlexTube Go-To, but the altitude motor keeps slipping even with no eyepiece in it. Do you have any advice?

KEN FERGUSON

The Sky-Watcher Skyliner 250PX FlexTube Go-To is a motorised Dobsonian telescope on a mount that allows both manual and Go-To control. To allow this dual functionality to work, there are clutches on both the azimuth and altitude drives, and dual encoders to keep tabs on where the telescope is pointing.

The clutch tension has to be within certain tolerances: tight enough to drive the telescope under the control of the hand controller, but slack enough to allow slippage when pushing the mount to a new position by hand. Although this setting is preset at the factory, it can be too loose and it seems most likely that this is the case with your Dobsonian.

▲ Adjusting the clutch tension of this Go-To Dobsonian is best left to a dealer

The clutch tension can be adjusted by removing the cover from the altitude motor and adjusting the tension bolt but, unless you know exactly how to do this, you would be better advised to have this adjustment made by your dealer.

STEVE'S TOP TIP

What is vignetting?

Vignetting is a reduction in image brightness at the edges of the field of view. There are two possible causes for this, the lens/mirror design or an obstruction in the light path.

Telescopes bend the light that passes through them, forming a cone of light that forms a circular image at the focus point but there is always a brighter central region in the cone leading to light fall-off towards the edges.

Anything that intrudes into the light cone will attenuate the light so telescope designers go to great lengths to produce focusers and adaptors with wide apertures.

Steve Richards is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★☆ Very good
★★★☆☆ Good
★★☆☆☆ Average
★☆☆☆☆ Poor/Avoid

90
A tiny telescope, but don't let that fool you: the Altair 60 EDF is a capable doublet refractor

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Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**

FIRST **LIGHT**

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/alt60edf**

Altair 60 EDF doublet refractor

A palm-sized telescope that you can pocket for a quick getaway

WORDS: PAUL MONEY

VITAL STATS

- **Price** £399
- **Aperture** 60mm (2.36 inches)
- **Focal length** 360mm (f/6)
- **Optics** Multicoated S-FPL53 ED doublet lens
- **Mounting** Hinged single tube ring and tripod foot
- **Focuser** Dual-speed rack and pinion with 10:1 fine focusing
- **Weight** 1.5kg
- **Extras** Retractable dew shield, 2-inch to 1.25-inch adaptor, camera angle adjuster
- **Supplier** Altair Astro
- **www.**altairastro.com
- **Tel** 01263 731505

They say small is beautiful and in the case of the latest short focus refractor from Altair Astro that certainly is an apt description. The 60 EDF is a lightweight tube assembly that weighs 1.5kg and almost fits in the palm of your hand. It's ideal for a multitude of purposes, including as a travel scope and for wide-field imaging. It is suppled as an optical tube only, giving you the flexibility to use your own star diagonal and eyepieces for visual observations, as we did for the review.

Also in the box is an extendable dew shield. The telescope tube has a hinged mounting ring with a foot for attaching to a tripod, and the focuser has 75mm of travel and a tensioning screw to prevent heavy accessories from slipping. It also sports a camera angle adjuster, which allows you to rotate your camera without the need to rotate either the telescope tube or the focuser.

For our review, we used the 60 EDF as a simple visual wide-field scope attached to a standard photographic tripod, on a Sky-Watcher Star Adventurer tracking mount for astrophotography with a DSLR, and on an NEQ6 mount for imaging with an Altair GPCAM2 290C CMOS camera for close-up imaging. For our visual tests, we added a dielectric star diagonal and a range of eyepieces.

SKY SAYS...
If you are looking for a capable scope that can cover wide-field visual observing and imaging, the 60 EDF does the job

Using a 2-inch 26mm eyepiece we examined the field of view using Deneb in Cygnus as our test star. The view was pin sharp across 85 per cent of the view, with only slight distortion at the edges and little sign of colour fringing, showing that the lens design was doing its job. We then took a tour around the best targets in the sky at the time, our first port of call being Orion, where we discovered that we could fit the three stars of Orion's Belt and most of Orion's Sword into the same field of view, and enjoyed the wisps of nebulosity of the Orion Nebula. Swapping to a 2-inch 9mm eyepiece gave enjoyable views of the nebula, with the stars of the Trapezium Cluster glittering at the centre.

Points of view

We also used the 2-inch 26mm eyepiece on the Pleiades and the Andromeda Galaxy, tracing out the latter's disc for several degrees. Naturally some targets required 9mm or 10mm eyepieces to give a bit of extra magnification, and with these we took in the galaxy pair M81 and M82, the wide double star Mizar and Alcor, and the Beehive Cluster in Cancer – which was particularly good in our 100° wide-field 9mm eyepiece. With the 2-inch 26mm eyepiece (with a 70° field of view), we were able to see plenty of the Milky Way surrounding the ▸

GRAB AND GO FOR ALL OCCASIONS

If a telescope is large and heavy, then there is a good chance it may not get used that much, but small, short focal length scopes such as the 60 EDF come into their own by being incredibly portable and versatile. Weighing 1.5kg and only 23cm long, it easily fits into luggage – making it a great scope to take to a dark site or on holiday without feeling like you are carrying an observatory around with you.

The 60 EDF can be attached to a simple tripod for basic wide-field observing with a star diagonal and eyepieces, or attached to a tracking mount for a simple and quick astrophotography setup that you can take anywhere. Add in an erecting diagonal and you even have a spotting scope for nature and wildlife use during the daytime.

OPTICS

The front lens element consists of a synthetic fluorite S-FPL53-based doublet objective lens with multicoatings on all optical surfaces for good control of colour correction and the lens is slightly oversized to provide better edge quality.

CAMERA ANGLE ADJUSTER

Your celestial targets will not all be orientated the same way in the night sky. The camera angle adjuster allows an attached camera to be rotated, yet held firmly in place, without affecting focus or having to rotate either the focuser or tube.

DEW SHIELD

The dew shield was very smooth in operation. It is retractable, and only adds 7cm to the scope's length when extended. It worked well under moderately damp conditions, allowing us to spend an hour imaging before the lens began to dew up.

HINGED MOUNTING RING

This is a very light telescope, so it doesn't require normal tube rings. Instead it relies on a hinged single tube ring and tripod foot. The tube ring can be loosened to help rotate the tube and the foot has three M6/¼-inch in-line holes for attaching to a tripod.

FIRST LIGHT

SKY SAYS...
Now add these:
1. Altair 60 EDF 1.0x flattener
2. Altair Hypercam IMX183C camera
3. iOptron SkyGuider mount

FOCUSER
The 2.5-inch rack and pinion focuser has 75mm of travel and offers dual-speed 1:10 fine focusing. There's also a tension adjustment screw, and this allows for heavy equipment such as large cameras to be attached and locked, so the focus doesn't slip during imaging.

▸ Double Cluster in Perseus – indeed, this combination was ideal for scanning star fields.

We then attached the 60 EDF to a Sky-Watcher Star Adventurer portable tracking mount and added a Canon EOS 50D DSLR, happily taking two-minute, wide-field exposures of the Pleiades and the Andromeda Galaxy with pleasing results. The 60 EDF is particularly suited to such tracking mounts, making it great for taking away on holiday to capture deep-sky vistas abroad. The mounting foot on the 60 EDF is ideal for such a mount of this size; should you wish to attach the scope to a larger mount, you'll need a 200mm Vixen bar.

When we used our own Vixen bar to attach the 60 EDF to a NEQ6 mount it did feel like overkill, yet by doing so we could take a variety of long exposures with our GPCAM2 290C colour camera and capture wonderful detail in the Orion Nebula. We found that we were able to frame the nebula easily by using the camera angle adjuster.

If you are looking for a capable telescope that can cover wide-field visual observing through to imaging, and is straightforward in use throughout, then the 60 EDF certainly does the job. Ⓢ

VERDICT

BUILD AND DESIGN	★★★★★
EASE OF USE	★★★★★
FEATURES	★★★★☆
IMAGING QUALITY	★★★★☆
OPTICS	★★★★½
OVERALL	★★★★½

WWW.THESECRETSTUDIO.NET, PAUL MONEY X 3

▲ The Orion Nebula imaged with the GPCAM2 290C: a stack of 60 five-second exposures at a gain of five and 80 20-second exposures at a gain of 15, and slightly cropped

▲ The Pleiades in Taurus, imaged with a DSLR, stacked from 15 two-minute exposures at ISO 800

▲ The Andromeda Galaxy, imaged with a DSLR, stacked from 15 two-minute exposures at ISO 800

"Dave had just flown all the way from Alpha Centauri."

"*Theakston's Best Bitter please,*" he asked the android behind the bar. Our hoverstools whooshed us to a table where our pints waited, golden as a Neptunian sunset. *"You know, they've been brewing this cask beer the same way for over 2,875 years,"* Dave said. *"Bet it still tastes just as good too,"* I replied. Dave was now in full flow. *"And they use the same mash tun from 1875. So every pint of cask Theakston's in the entire universe ever has come from just one mash tun, including everyone's in this bar now."* I looked around the Time Traveller's Arms. Rick the Robot was nursing his pint and busy snacking on iron-filing flavour crisps. In the corner sat Artus Minor and his wife Debbie from Whitby. And across the room the Andromeda twins were playing six dimensional dominoes. *"What you are witnessing, my friend,"* Dave explained, *"is intergalactic harmony on a grand scale."* His eyes were bright with belief. *"And it's all down to Theakstons and their 2,875 year old mash tun!"* Honestly, I really do sometimes wonder what planet Dave is on.

"Boy, was he thirsty."

THE TALK OF THE PUB.

FIRST **LIGHT**

See an interactive 360° model of this mount at **www.skyatnightmagazine.com/exos2pmc8**

Explore Scientific Exos2 PMC8 Wireless Go-To mount

A mount with a daring design feature – there's not a controller in sight

WORDS: NICHOLAS JOANNOU

VITAL STATS

- **Price** £849
- **Load capacity** 12.7kg
- **Hand controller** None, system uses windows devices as an interface
- **Database** 70,000 objects
- **Flash upgradeable** Yes, via internet software download
- **Autoguider port** ST-4
- **Wireless control** PMC8 using ExploreStars app
- **Weight** 13.5kg (without counterweights)
- **Supplier** Telescope House
- **www.**telescopehouse.com
- **Tel** 01342 837098

WWW.THESECRETSTUDIO.NET X 6

With an increasing number of Wi-Fi controlled devices available in today's marketplace, Explore Scientific's Exos2 PMC8 is a bold new offering. This mount is completely centred around its PMC8 Wi-Fi control system, doing away with the traditional handset controller completely. Control of the mount is instead achieved by pairing any Wi-Fi enabled Windows device (be it a laptop, tablet or smartphone) with the mount's own Wi-Fi unit and then using the ExploreStars Open Go-To app. Support for other platforms is reportedly in development.

The mount has an ST-4 port for autoguiding and is the first to feature a wireless driver for the popular ASCOM platform of open source telescope control software. The Wi-Fi unit is separate from the mount body, attaching to the tripod legs via a bracket. The power supply for the Wi-Fi unit also powers the mount's motors – control cables run from the Wi-Fi unit's ports to the RA and dec. motors.

The ExploreStars Open Go-To app itself offers a fresh take on telescope control and is especially useful for beginner and intermediate astro imagers, as its graphical interface guides you step by step though the set up and alignment procedure, and there are many pictorial references of the sky to help you along the way. The general layout of the interface is clear and uncluttered, separating the system's many functions and menus from the mount's slewing controls.

> ***SKY SAYS...*** The mount worked well, placing our chosen targets within the central 75 per cent of the field

Automatic slewing

The menu system gives you access to the large database of objects, which are neatly organised into categories and subcategories. All named objects in the database are accompanied by a good amount of clear and interesting information, with pictures of each for you to look through. There is also the option to slew the telescope to the current object selected if it is visible above your horizon. When manually slewing the mount, you can choose to use the onscreen directional pad or joystick, selecting the slew speed via a number pad or the distance from the centre of the joystick. The greater the distance, the faster the slewing speed. ▸

WI-FI CONTROL AND GO-TO APP

The Exos2 control system uses a two-channel multi-processor microcontroller with a massive eight CPUs, hence the PMC8 title. This offers a great enhancement in processing power over the usual single processor used in most telescope control Go-To handsets. Along with this processing power, it also has great choice over which type of device to connect with autoguiding for astrophotography, a wireless ASCOM connection, and the ability to gather current date, time and location data from your windows device, making the setup easier and more convenient.

The connection to ASCOM allows you to tweak and modify the mount's control systems in a customised manner, either by using a pre-existing ASCOM add-on or by programming your own modifications. The ExploreStars Go-To app's graphical user interface is well designed, intuitive and easy to use, even for beginners with little experience of equatorial mounts and limited knowledge of the night sky.

BELT-DRIVEN STEPPER MOTORS

The mount has belt-driven dual stepper motors for greater smoothness when slewing and increased tracking accuracy. The combination of a fiberglass-reinforced neoprene belt and Nema 11 bipolar stepper motors reduces any backlash that might be associated with a purely gear-driven system to a minimum.

POLARSCOPE

The mount has a built-in, illuminated-reticle polarscope. The sky alignment etchings in the polarscope eyepiece are clear and easy to use. The red LED illumination can be dimmed and ensures that you can always see the alignment etchings against a dark sky, while also helping you to retain dark-adapted vision.

HIGHLIGHTED MANUAL CONTROLS

The manual controls for the Exos2 PMC8 are highlighted in bright silver to contrast with the black metal and plastic that the main body consists of. In short, anything that is to be screwed in, adjusted, locked or bolted stands out well, making all of the various pieces easy to locate.

TRIPOD

The tubular steel tripod that has a built-in bubble level to help with accuracy when setting up. Each leg has two locking bolts to prevent any slippage. The tripod spreader also acts as an accessory tray that can hold your various pieces of equipment.

FIRST **LIGHT**

> ***SKY SAYS…***
> **Now add these:**
> **1.** Revelation BC169 12V mains power supply
> **2.** QHY PoleMaster polarscope
> **3.** PoleMaster adaptor

▸ The mount is relatively quiet when in operation, with the stepper motors making a soft hum, although it does build up to a slightly musical note when slewing at maximum speed. Externally it is constructed mostly of metal, with the motor housing a hard plastic. A tubular steel tripod holds the mount head in place well, and vibrations in the eyepiece when observing died down within 10 seconds of the mount being intentionally bumped.

With the mount levelled and polar aligned, we first tested for any variance in the plane of the puck that holds the telescope and the mount's axis (cone error). There was a very slight misalignment evident that was easily adjusted. After going through the alignment procedure, we tested the Go-To function using a 32mm Plössl eyepiece and a 1,000mm focal length f/5 Newtonian telescope. The mount worked well – in each instance it placed our chosen target within the central 75 per cent of the field of view, even when slewing to objects in opposite areas of the sky. Once your selected target has been acquired by the mount it will automatically track it through the sky until you give it another command, allowing easy observation and the opportunity for some astrophotography.

The Exos2 PMC8 is portable enough to travel, and its high-quality stepper motors and control system should produce good overall results in the field. In the process of testing from our London-based location we did occasionally experience loss of the Wi-Fi connection to the mount. After some quick and friendly correspondence with the manufacturer, Explore Scientific is now looking into the issue, which it has assured us is not a common occurrence. Other than this anomaly, the mount performed well in all other respects. Ⓢ

VERDICT

ASSEMBLY	★★★★☆
BUILD AND DESIGN	★★★★☆
EASE OF USE	★★★★☆
GOTO/ TRACKING ACCURACY	★★★½☆
STABILITY	★★★½☆
OVERALL	★★★★★

BATTERY PACK

Included in the package is a 12V Battery pack that uses eight D batteries to power the Wi-Fi controller and subsequently mount itself. A battery pack grants you the freedom to set the mount up at any location with ease. We would recommend using only high-quality batteries for the best performance.

WWW.THESECRETSTUDIO.NET X 2

FIRST **LIGHT**

See an interactive 360° model of this camera at www.skyatnightmagazine.com/atik16200

Atik 16200 cooled mono CCD camera

A chunky cube camera that delivers delightful deep-sky shots

WORDS: TIM JARDINE

VITAL STATS

- **Price** £2,979 monochrome, £2,899 colour
- **Sensor** Kodak KAF 16200
- **Pixels** 4,499x3,599 (6μm square)
- **Dimensions** 11x11x11cm without handles (11x11x14cm with handles)
- **Gain factor** 0.6e/ADU
- **Read noise** 9e- typical
- **Back focus** 19.5mm +/–0.5mm
- **Exposure range** 0.2 seconds to unlimited
- **Weight** 1.3kg
- **Supplier** Atik Cameras
- **www.**atik-cameras.com
- **Tel** 01603 740 397

Anyone familiar with the Atik range of astronomy cameras might be forgiven for not recognising the 16.2-megapixel Atik 16200 as being part of the family. Apart from the metallic red livery, this camera has been designed from the outset to be different, and yet it maintains the reliability and usability synonymous with the Atik name.

There's no getting around the fact that the Atik 16200's cube design makes it both large and relatively heavy, though there are handles on the rear of the camera body to help you attach it to a setup and fit accessories. As this is a mono camera, we fitted our own filter wheel plus colour filters to the front, these being necessary to create colour images. A one-shot-colour variant of the camera is available.

Such a large casing has advantages, however – in this case a huge heat sink and fan fitted to the dual-stage electronic cooling system. Astronomy cameras produce much cleaner images if the camera sensor is chilled, and the Atik 16200 aims to provide cooling capability up to 50°C below ambient temperature. Keen to test this, we set the cooling to maximum and watched the readout as the temperature fell. Within five minutes the sensor had been cooled from 10°C to –37°C, and the camera held that temperature steadily.

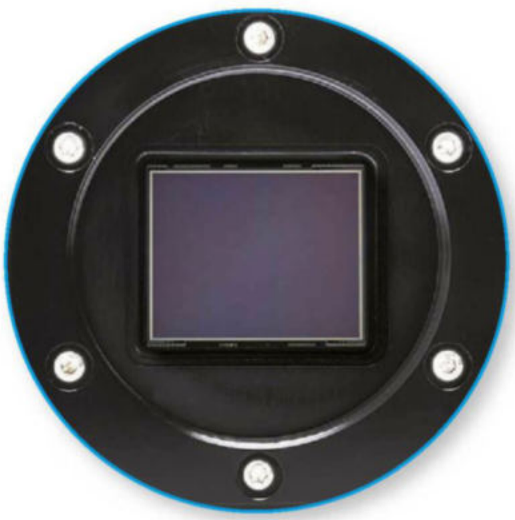
SKY SAYS... The minimum 0.2-second exposure limits the camera to deep-sky objects, but in this it excels

Preventing condensation in the rest of the camera interior is another concern, and problems can occur in some designs with rapid temperature drops. In the 16200 Atik has neatly avoided issues with frosting and dew on the sensor chamber by sealing the camera body and purging it with argon gas, via an unobtrusive valve fitted to the side of the camera. We watched carefully for any problems with the CCD frosting as it cooled, and there were none.

Cool performer

Impressive cooling aside, we wanted to see how the camera performed when pointed at the sky. Each full-size image takes around 18 seconds to download via the USB 2.0 connection – something that prolongs the framing and focusing process slightly. Once set, we aimed for NGC 281, the Pacman Nebula in Cassiopeia, and took a series of 30-minute exposures using a narrowband filter, a useful workaround given that there was a bright Moon around.

We were pleased to see that our images showed little noise over the long exposures. A few small, squiggly and random artefacts were present, but these were easily removed by stacking multiple images. There was no sign of star bloating, and good overall response to the available signal from the target. Subsequent exposures of varying lengths and through a range ▸



WWW.THESECRETSTUDIO.NET X 4

A SENSITIVE SOUL

The beating heart of this Atik camera is a Kodak KAF 16200 CCD sensor, which boasts a 4,499x3,599 pixel array (where each pixel is 6μm square). It's a 16-bit, APS-H large format sensor and it's an almost ideal match for a number of telescopes, offering a large imaging area and high resolution. For review purposes we used a 6-inch, f/7 refractor, but the 6μm square pixels will allow this camera to be used effectively on short focal length telescopes and longer ones – perhaps even a modern Schmidt-Cassegrain with a reducer, keeping the imaging resolution within sensible boundaries. At 35mm across the diagonal, this camera allows you to get maximum use of a telescope's flat, coma-free image field.

Large format CCDs tend to be correspondingly expensive. Although the Atik 16200 is not really aimed at beginners, its comparatively modest price makes it desirable to dedicated amateur astrophotographers wishing to invest in new equipment – perhaps a one camera solution that can be effectively used on a range of telescopes.

WEIGHT

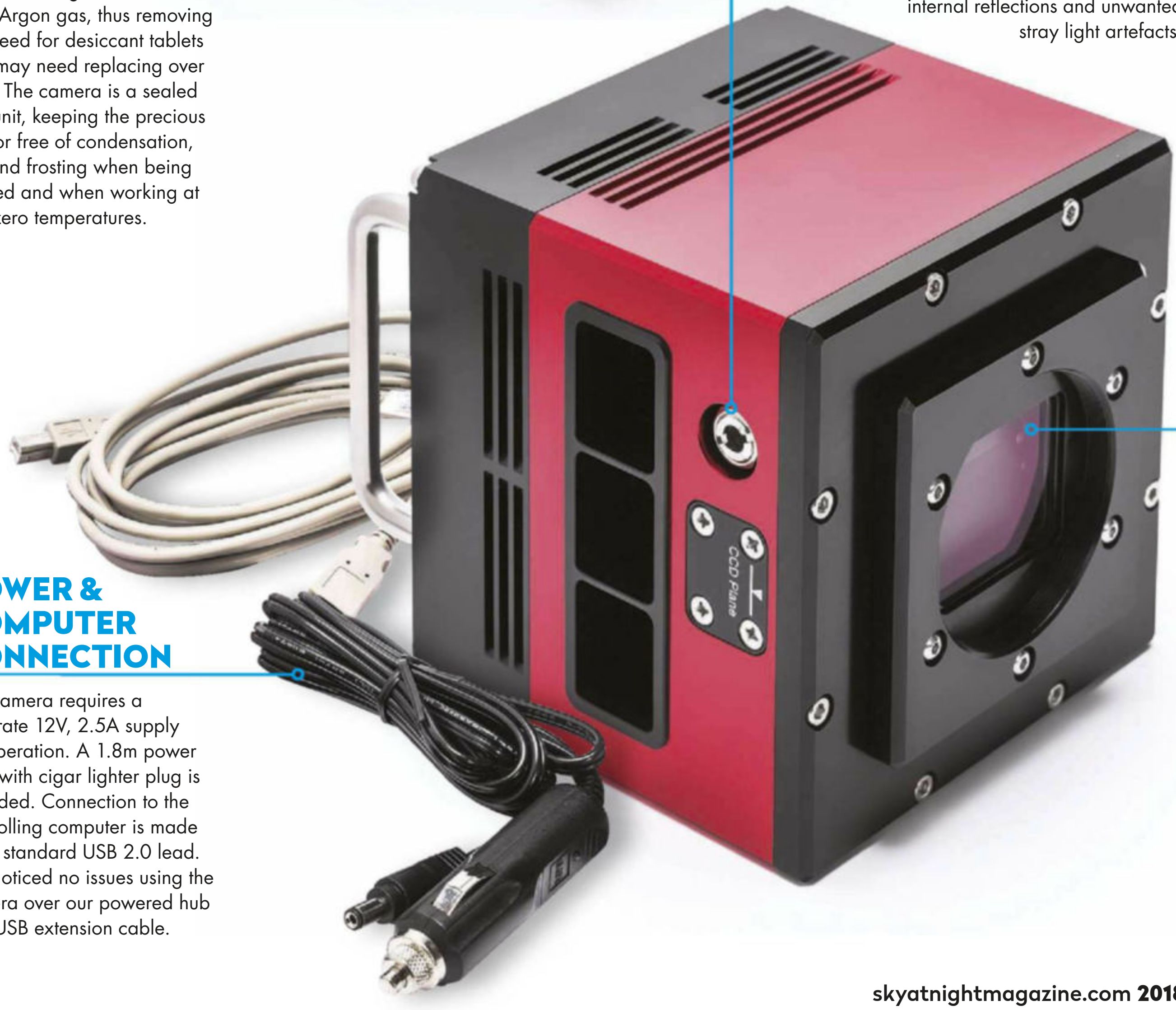
The camera is solidly constructed from quality materials and weighs a hefty 1.3kg, perhaps pushing the payload limit of some mounts. Care needs to be taken to avoid balancing issues when using this camera with certain shorter telescopes, or those that are heavier at the rear, especially if the camera is combined with a filter wheel.

CCD OPTICAL WINDOW

Acting as a barrier between the camera sensor and the outside world, a fixed quartz optical window ensures that nuisance dust is prevented from settling on the sensor. This window is treated on both sides with a broadband anti-reflection coating to avoid internal reflections and unwanted stray light artefacts.

ARGON PURGING PORT

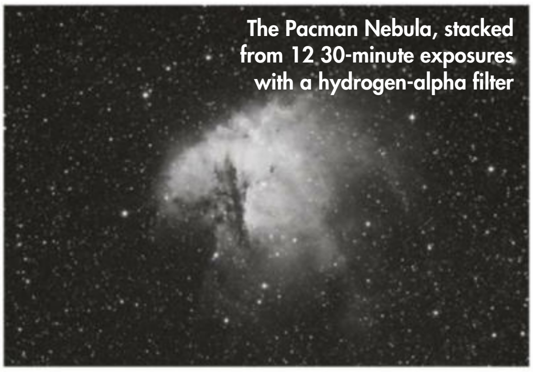
Used for filling the camera with Argon gas, thus removing the need for desiccant tablets that may need replacing over time. The camera is a sealed dry unit, keeping the precious sensor free of condensation, ice and frosting when being cooled and when working at sub-zero temperatures.



POWER & COMPUTER CONNECTION

The camera requires a separate 12V, 2.5A supply for operation. A 1.8m power lead with cigar lighter plug is provided. Connection to the controlling computer is made via a standard USB 2.0 lead. We noticed no issues using the camera over our powered hub and USB extension cable.

FIRST **LIGHT**


The Pacman Nebula, stacked from 12 30-minute exposures with a hydrogen-alpha filter

▸ of filters demonstrated nicely that the custom electronics within the camera work efficiently with the sensor to produce smooth, clean images. After stacking and processing, we discovered that the camera had picked up a wealth of faint detail, including emission and reflection nebulosity.

In addition to the reassuring hum of the cooling fan, each exposure produces an audible click, indicating the operation of the mechanical shutter. With large sensors such as this one, taking reliable flat frames is normally an essential part of the imaging process; the shutter meant that we had to alter our standard method of taking flat calibration images, as short exposures left a trace of the mechanism in action on the image. Eventually we settled on a method using a dimly lit white panel.

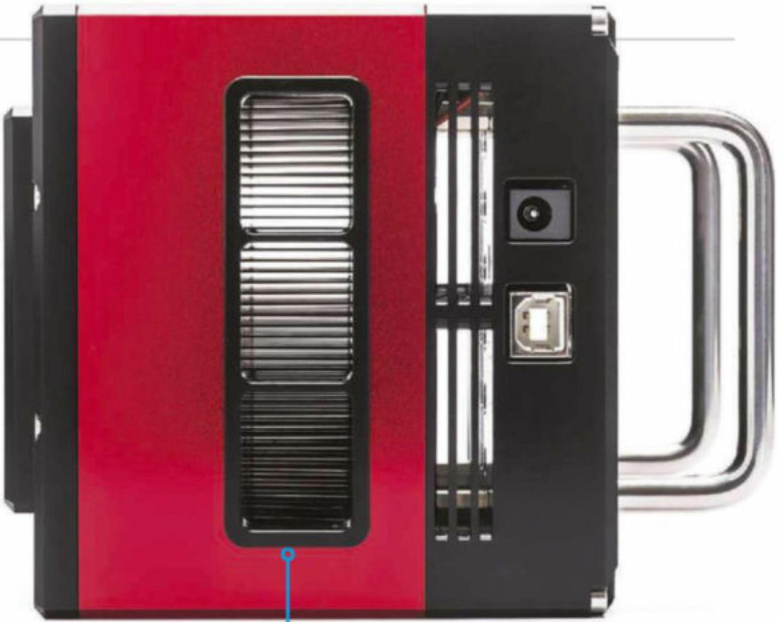
The minimum possible exposure of 0.2 seconds limits the camera to photographing deep-sky objects, but in this it excels. Beyond the Pacman Nebula, we were able to capture images of the Pleiades in Taurus, the Flaming Star Nebula in Auriga and the iconic Horsehead Nebula in Orion surrounded by a faint cloud of emission nebulosity.

The Atik 16200 is a heavy duty and very capable camera for deep-sky imaging, with excellent low-noise ability. Its almost industrial cooling capabilities allow it to take remarkable large format astrophotos. Ⓢ

SKY SAYS...
Now add these:
1. Atik EFW3 seven-position filter wheel
2. Atik off-axis guider
3. Atik Titan guide camera

VERDICT

BUILD AND DESIGN	★★★★½
CONNECTIVITY	★★★★☆
EASE OF USE	★★★★☆
FEATURES	★★★★½
IMAGING QUALITY	★★★★½
OVERALL	★★★★½



HEAT SINK & FAN

CCD sensors produce internal heat when taking long exposures, leading to noise problems in pictures. The large heat sink and fan quickly removes and dissipates heat, allowing the thermoelectric cooling to reduce the camera's temperature and maintain it at a level set in control software, an important requirement for calibration images.


The Horsehead Nebula, stacked from 10 hours of R G and B image data recorded at several exposures


◂ The Pleiades, stacked from 7.5 hours of image data recorded for R, G, B and Luminance

Books

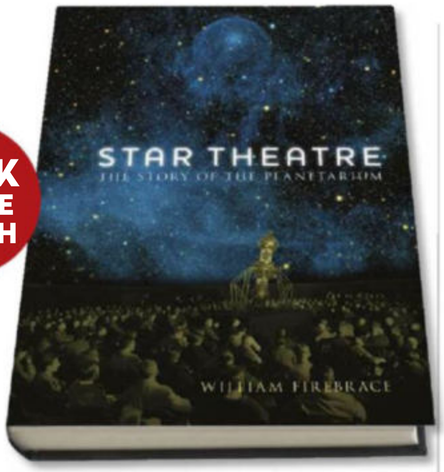
New astronomy and space titles reviewed

RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

Star Theatre
The Story of the Planetarium

BOOK OF THE MONTH



William Firebrace
Reaktion Books
£25 ● HB

Planetariums bring the wonders of the night sky to the dwellers of our light-polluted cities; those who might otherwise remain ignorant of its allure. A planetarium is a cinema, a civic building, a museum, a temple and a theatre.

Star Theatre presents the history of the planetarium, from the first modern one built on the roof of the Zeiss optics factory in the former East Germany, to its more recent counterparts in countries across the globe. The author explores earlier mechanisms for depicting the Solar System, before turning his attention to the evolution of the planetarium as we know it today. This includes the intricate design of the buildings themselves and the complicated projection systems housed within them.

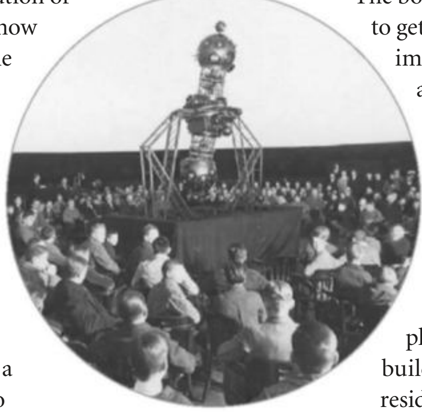
We learn about the creation of the parabolic ferrocement dome over the Moscow Planetarium, which had a ratio of shell thickness to internal volume less than that of an egg. And we learn about the construction of the Wolfsburg Planetarium in Germany, which was built by Zeiss in return for 10,000 Volkswagen Golf cars for the citizens of the German Democratic Republic.

Star Theatre provides a masterful and well-researched examination of the architectural heritage and cultural significance of planetariums, such as the role of the Zeiss projector in fostering relations between Soviet-controlled East Germany and the rest of the world. It also contemplates how the development of planetariums has been influenced – indeed, challenged – by discoveries in astronomy such as black holes, gravitational waves and the theory of dark matter, as well as the growing capabilities of projection technology.

The book does take a while to get started, but it improves once the author gets onto the subject of modern planetariums and those who have designed them. And it comes alive when considering the architecture of planetariums and the buildings in which they reside. It also includes some excellent images.

Star Theatre is very clearly, though, a book about architecture rather than about astronomy. If you are an architect with an interest in astronomy, or vice versa, you will love this book. If you are not, then I fear that you – like me – may be a little disappointed. ★★★★☆

SIMON PERKS *is a science writer and amateur astronomer*



The first show for schoolchildren at the Jena Planetarium with the Zeiss Model II projector

CARL ZEISS ARCHIVE

TWO MINUTES WITH
William Firebrace

How did the earliest planetariums operate?
The earliest planetariums, such as the 17th-century Gottorf Globe in Germany, were large rotating spheres that a small number of visitors could enter, with effects produced either by candles illuminating paintings of the constellations, or light entering through small holes drilled in the shell. The first modern planetarium was produced in 1912 by the optical engineer Walter Bauersfeld, working for the firm of Zeiss in Jena, Germany. Bauersfeld invented not only the first projector, a very complex device which could beam the apparent movements of the planets and stars onto a domed screen, but also the first ultra-thin geodesic dome, which was constructed on the roof of the Zeiss factory.

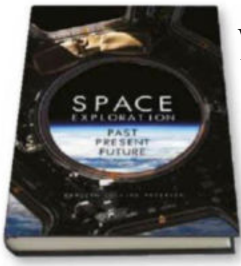
Can you remember your first visit to a planetarium show?
As a child, I was taken to the London Planetarium, and then we visited the neighbouring Madame Tussauds waxworks. I remember being astonished by the wonderful light show, and confused by its relationship to the wax figures of celebrities and criminals!

What have been the biggest developments in planetariums?
The evolution of powerful digital projectors that provide cinematic effects, linked to fundamental changes in the nature of astronomy – from understanding the sky as seen from planet Earth, to the notion of an expanding Universe of vast size.

WILLIAM FIREBRACE *is an architect and the author of* Things Worth Seeing, Marseille Mix *and* Memo for Nemo

Space Exploration

Carolyn Collins Petersen
Amberley Publishing
£20 ● HB



What does it take to build a spacefaring civilisation? Time? Technology? Brains? Big bucks?

This attractive hardback addresses space exploration's big picture, from humankind's Earthbound toddling to strident robotic interplanetary reconnoitre and future interstellar flight. Our foundation was the nascent dreams of ancient skygazers, rudimentary kites and Chinese gunpowder arrows. Thence came hot air balloons, airships and combat aircraft, each a progression to the high-powered rocket technology synonymous with today's Space Age. Touched on are the key visionaries, scientists, engineers and 'space sailors', those who triumphed and failed, in the warfare-driven race to conquer space.

After itemising the past and present global space agencies and institutions that enable our reconnaissance of the Solar System and beyond, author Carolyn Collins Petersen discusses the international treaties, laws and policies constraining exploration. We gain an insight into the thrust of corporate competitiveness, the benefits and costs of fledgling commercialisation and the possible price of prospective exploitation as our 'grand enterprise' continues.

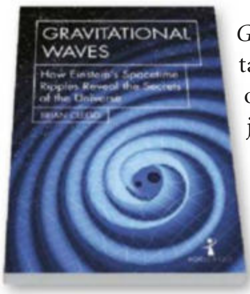
By summarising mission successes, defining existing global spacefaring infrastructure and assessing the reality of colonising the Moon, Mars and beyond, Petersen admirably tackles her own question. This is an up-to-date reference guide as well as an introduction for anyone seeking factoids of the Space Age. Niggles? It's a little repetitive and perfunctory in places. There are vocabulary omissions and one glaring error: "three astronauts landed on the Moon on 16 July 1969". But, overall, it's a solid launch pad to inspire deeper exploration.

★★★★☆

JANE GREEN *is a presenter, broadcaster and author of the* Haynes Astronomy Manual

Gravitational Waves

Brian Clegg
Icon Books
£7.99 ● PB



Gravitational Waves takes the reader on a whirlwind journey through the field. It not only touches on the necessary points we need to understand what gravitational waves are, but delves in to the history, the methods used to find them, the elation of the first detection and what the future may hold. Not bad for just over 150 pages!

This is a very easy read and tackles what can seem a complicated subject in an approachable manner. Author Brian Clegg does a good job capturing the excitement and events around the first detection. A really nice touch is his occasional use of common phrases by those internal to the LIGO Scientific Collaboration and Virgo Collaboration, without losing the reader in jargon.

There are unfortunately some inaccuracies in the book. Some are minor, such as an erroneous repeated mention of a 15 September event. However, the characterisation of the 4 January event as 'lucky' is simply not true, nor the downplaying of the significance of the 26 December event to astronomer partners. The sub-chapter entitled 'Secrets and Lies' felt particularly critical of the scientific process employed by some 1,500 scientists from across the globe in validating and presenting, in 13 publications, the first detection of gravitational waves in just five months.

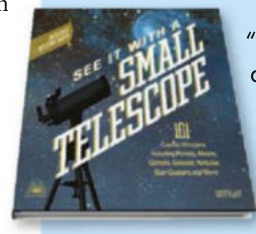
All that said, this book does present a nice introduction to gravitational waves for those who aren't experts, and gives an insight into the wonderful period around the first detection of gravitational waves.

★★★½☆

LAURA NUTTALL *is a Sêr Cymru MSCA COFUND fellow at Cardiff University and a member of the LIGO Scientific Collaboration*

See It With A Small Telescope

Will Kalif
Ulysses Press
£14.99 ● PB



"Under normal dark-sky conditions … there are approximately 6,000 objects visible to the naked eye," reads the opening line of *See It With a Small Telescope*. Surrounded as we are by jaw-dropping photos of astronomical objects, it is easy to become underwhelmed by visual astronomy.

This book aims to set realistic expectations of what you will see through a small telescope whilst also asserting how awe inspiring these views are. There are chapters on telescope setups and lessons on how to navigate the night sky, followed by discussions of celestial objects by category. It begins with targets that are the easiest to locate, before moving on to nebulae, galaxies and other objects.

The book is written in a very approachable style and each target object includes coordinates, interesting information, an easy-to-follow finder chart and instructions on how to star hop to it. Most important is the ocular view, which shows how each object may look through a small telescope.

There are occasions in when the ocular view is a little unrealistic, and the observing data assumes the reader is in the US, so it won't always apply to readers in the UK, which is farther north. However, this book would be perfect for beginners who are starting out with their first telescope and aren't yet confident in using it, or even for experienced astronomers who would like to reconnect with visual astronomy.

★★★☆☆

MARY MCINTYRE *is an astronomer, astrophotographer and science writer*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

1 Omegon Atmospheric Dispersion Corrector

Price: €149 • **Supplier:** Omegon
www.omegon.eu

By reducing the distorting effects of the atmosphere, this dispersion corrector can give you clear views of planets low in the sky.

2 PrimaLuceLab SESTO SENSO Stepper Motor

Price: £329 • **Supplier:** 365 Astronomy
020 3384 5187 • www.365astronomy.com

Control your focuser remotely with this stepper motor. It's designed to keep vibrations to a minimum and maintains a precision of 0.7µm.

3 Ultima LX Eyepieces

Price: £50 • **Supplier:** Green Witch
01767 677025 • www.green-witch.com

The non-slip covering and ergonomic design of these 70° eyepieces make them easy to use even when wearing gloves.

4 Baader MPCC V-1 Mk-III Coma Corrector

Price: £169 • **Supplier:** Harrison Telescopes
01322 403407 • www.harrisontelescopes.co.uk

Eliminate coma, an optical aberration that distorts stars at the edge of a field of view, without reducing your focal length.

5 Sun Wall Hanging Print

Price: £8 • **Supplier:** Royal Observatory Greenwich
020 8312 6700 • https://shop.rmg.co.uk

This A3 print replicates an 1850 wall hanging of the Sun, featuring sunspots as well as the line-up of the planets, that was used to educate people about our Solar System.

6 Revolution Imager 60mm Zoom Lens

Price: £49 • **Supplier:** Modern Astronomy
020 8763 9953 • www.modernastronomy.com

This 6-60mm, f/1.6 30mm aperture lens can be combined with a lightweight camera to create a compact imaging setup that's great for travelling.

WHAT I REALLY WANT TO KNOW IS…
What is heating Enceladus?

Gaël Choblet is investigating how an icy satellite can maintain a subsurface ocean of hot water for billions of years

INTERVIEWED BY PAUL SUTHERLAND

One of the Cassini space probe's great discoveries while exploring Saturn and its moons was that one of those moons, Enceladus, is an active world containing an underground ocean of liquid water.

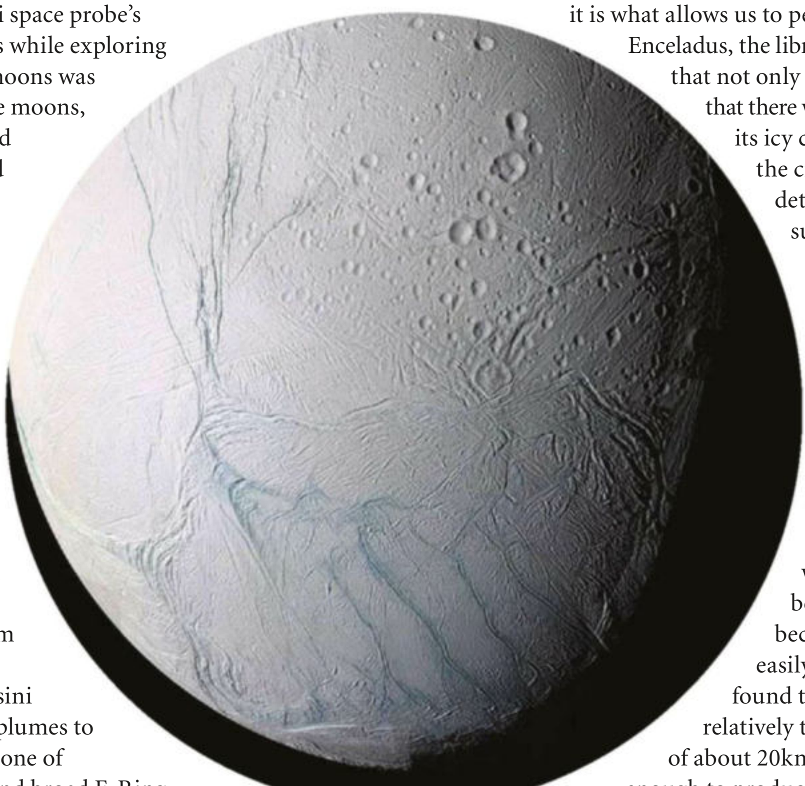
During the first year of the mission, several instruments recorded evidence for activity that is usually associated with the presence of energy. Some even revealed that long fractures in Enceladus's south polar region, known as tiger stripes, were hotter than their surroundings. Cassini also observed plumes of material being expelled from the moon's interior.

Later in the mission, Cassini was able to fly through the plumes to 'taste' them. It also studied one of Saturn's rings, the diffuse and broad E-Ring, into which Enceladus is feeding icy material. Analysing both the gas and the ice particles gave information about the moon's internal processes. Very small particles of silica, seen in the vicinity of Saturn, revealed some sort of interaction between rock and water at high temperature, greater than 90°C. They appeared to be tiny rock particles ejected by the spray from a reservoir of water beneath the surface of Enceladus.

Out in the cold

So how does a moon in the chilly outer Solar System come to have liquid water? It was soon realised that Saturn's own tidal forces are responsible. The gravitational energy from Saturn is pulling Enceladus about, causing it to deform, and part of this energy is converted into heat.

Quite late on in the mission, Cassini scientists discovered more important clues to the internal structure. Observations over time of control points on the surface of Enceladus showed that it was experiencing a significant rocking motion known as libration. Our Moon also shows libration, and it is what allows us to peer over its far side. For Enceladus, the libration was the final evidence that not only was water present, but also that there was a global ocean separating its icy crust from a solid core. If the crust was not completely detached, you wouldn't have such a large motion.



Enceladus's quartet of 'tiger stripes', visible near the moon's lower limb, are fractures in the icy crust

NASA/JPL

The amount of heat emitted from the south polar terrain of Enceladus was estimated to be around 15 gigawatts. In order to maintain the global ocean beneath the ice crust, the overall heat budget could even add up to 30 gigawatts. Early on, we thought this heat must be produced in the ice shell, because ice deforms more easily than rock. But when we found that the ice shell must be relatively thin, with an average depth of about 20km, we realised that was not enough to produce the heat observed.

We had to look elsewhere. The moon's core did not seem a very likely candidate because cold rock does not deform easily, so would be unlikely to produce so much heat. But Enceladus is small and gravity observations suggested that its core is less dense than usual rocks. We realised that it could be porous and filled with water. A core formed by a collection of sand or gravel, filled with liquid water, could dissipate the amount of heat energy observed.

The heating of Enceladus's surface is not uniform. Some regions, especially beneath the poles are warmer than, say, the equator. It seems that cold water from the ocean enters the core's permeable boundary, then rises again as hot jets reaching focused spots at the sea floor, promoting hydrothermal vents in the ocean that melt the ice crust above. This activity could have persisted for tens of millions to billions of years.

To find out more about Enceladus we really need to go back there. Fortunately the icy outer moons are being considered as potential targets by NASA. A mission to Enceladus would be relatively inexpensive because you can investigate its interior simply by flying through the plumes.

ABOUT GAËL CHOBLET

Gaël Choblet is a researcher at the University of Nantes in France with a special interest in what is going on inside the planets and moons of our Solar System.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THE SOUTHERN HEMISPHERE IN FEBRUARY

With Glenn Dawes

WHEN TO USE THIS CHART

1 FEB AT 00:00 UT
15 FEB AT 23:00 UT
31 FEB AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

FEBRUARY HIGHLIGHTS

Mars is in the morning sky. The planet forms a close double with mag. +2.6 Acrab (Beta[1] (β^1) Scorpii) on the 1st, the separation only 0.5°, though Mars is considerably brighter. On the 11th, the Red Planet meets its traditional 'rival', mag. +1.1 Antares (Alpha (α) Scorpii); they will be 5° apart and equal in brightness. Mars then moves below the star, with month end seeing the separation doubled. It brightens to mag. + 0.8 as it heads towards its impressive opposition in July.

STARS AND CONSTELLATIONS

Mag. –1.5 Sirius and mag. +0.4 Procyon are the alpha stars in the constellations of Orion's hunting dogs, Canis Major and Canis Minor. Although separated by 26°, they are in fact close neighbours to both the Sun and each other. Procyon is 11.4 lightyears away from us, Sirius closer at 8.6 lightyears, but they are only 5.3 lightyears between the two of them. Procyon has a closer neighbour still: mag. +9.9 Luyten's Star is only 1.1 lightyears from it.

THE PLANETS

Uranus is briefly visible in the evening sky, setting around 22:00 EST mid-month. About one hour later Jupiter rises. Mars arrives around midnight, followed by Saturn at approximately 02:00 EST – the best planetary action is definitely in the morning sky. The pre-dawn sees Jupiter high in the northeast, with Mars below it, near mag. +1.1 Antares (Alpha (α) Scorpii). Saturn is lower still in Sagittarius. The ringed planet is near the lid star of the Teapot asterism, which rises on its side.

DEEP-SKY OBJECTS

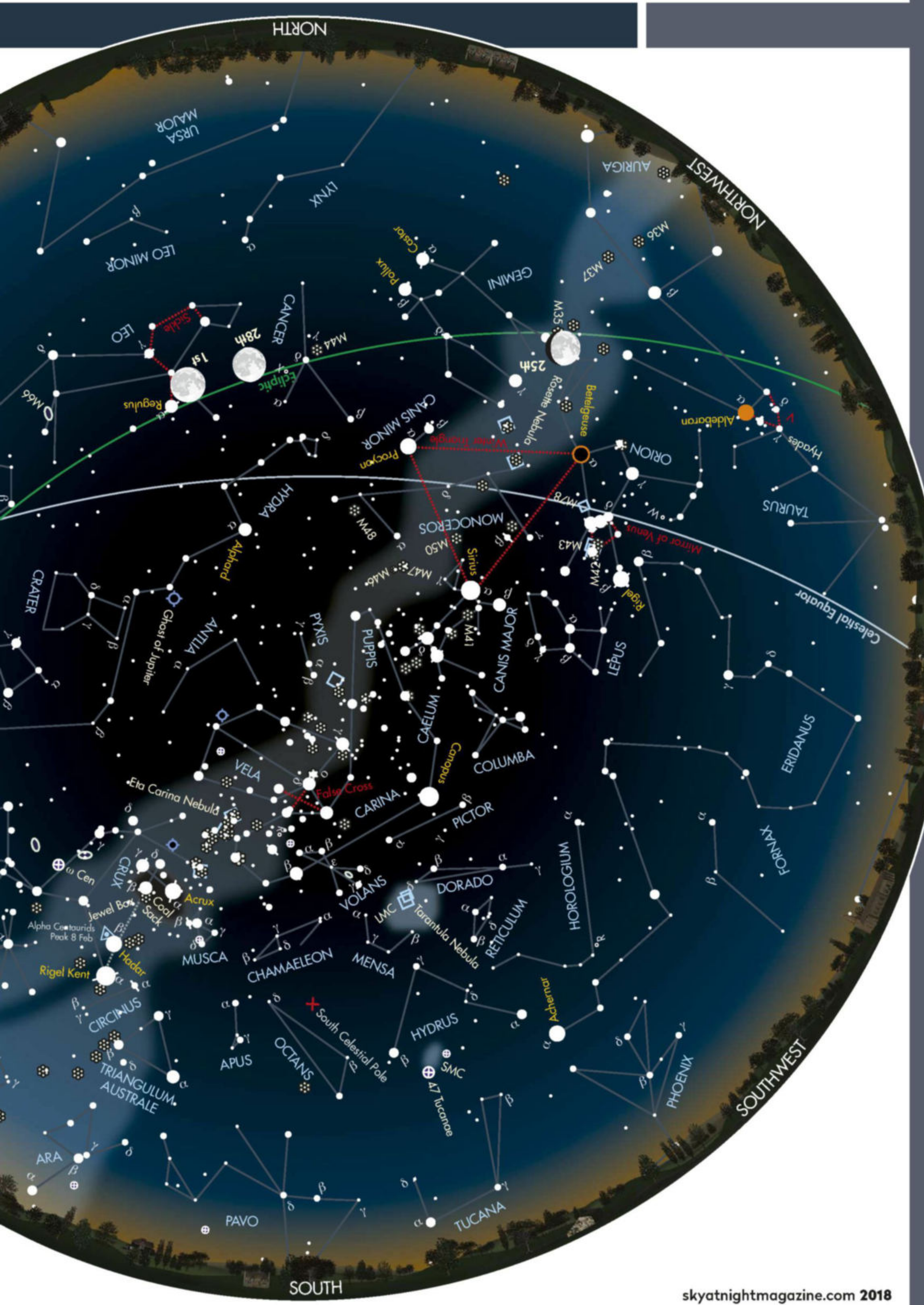
The northern end of Puppis is a star-rich region of the Milky Way. Approximately 13° east of the brilliant star Sirius (Alpha (α) Canis Majoris), are two distinctive open clusters that are visible in the same binocular field of view. The first is M47 (RA 7h 36.6m, dec. –14° 29'), a sparse, mag. +4.5 open cluster dominated by six bright stars, with another 60 fainter members arranged in scattered clumps and curved lines.

A short hop 1.3° east finds mag. +6.0 open cluster M46. In contrast to M47 it is densely packed, with its 100-plus stars (10th to 13th magnitude) more evenly spread. Near the cluster's northern end is planetary nebula NGC 2438 (pictured). At 150x magnification it shows a hazy, 1-arcminute disc with a defined edge.

CHART KEY

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: RUDOLF DOBESBERGER/CCDGUIDE.COM


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
LYNX
AURIGA
LEO MINOR
Castor
Pollux
GEMINI
M36
M37
M35
CANCER
M44
LEO
Sickle
Regulus
1st
28th
25th
Ecliptic
M66
Rosette Nebula
Betelgeuse
Aldebaran
Hyades
V
CANIS MINOR
Procyon
Winter Triangle
ORION
TAURUS
HYDRA
M48
MONOCEROS
M78
M50
Mirror of Venus
M43
M42
Alphard
Sirius
M47
M46
Rigel
Celestial Equator
CRATER
Ghost of Jupiter
ANTLIA
PYXIS
PUPPIS
M41
CANIS MAJOR
LEPUS
CAELUM
COLUMBA
Canopus
ERIDANUS
VELA
False Cross
Eta Carina Nebula
CARINA
PICTOR
HOROLOGIUM
FORNAX
ω Cen
CRUX
Acrux
Coal Sack
Jewel Box
Alpha Centaurids Peak 8 Feb
VOLANS
LMC
DORADO
Tarantula Nebula
RETICULUM
Hadar
Rigel Kent
MUSCA
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OCTANS
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